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148

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Burner Test

Results - English

The LINS Burner tests at Kvarntorp, 1959 - 1960

Summary and conclusions

The field tests at Santa Cruz, California, 1955 - 1959, resulted in the development of the so-called "sand burner". A number of 20 feet long burners in 50 feet deep casings were tested on a fairly large scale and some tests were made with longer burners in deeper casings. Before a commercial project was started, it was, however, desirable to obtain more experience on longer burners. For this purpose a series of tests were run in a part of the electrically heated, commercial Ljungstrom shale oil field at Kvarntorp, Sweden.

The first test was started in September 1959 with 10 36 feet long burners in 105 feet deep casings. The average heat input was 34,000 BTU/burner, hour. It was planned to run these burners for 6 months, but, mainly due to condensation of water in the casings during the start-up period, the fluidization was disturbed and several of the casings were damaged by heat. After about two months it was decided to shut down the remaining, undamaged burners and start a new test.

Thus 14 new burner wells were prepared and put in operation in April, 1960. Some changes were made in the burner and casing design, allowing higher heat inputs. The only important disturbance that occurred, was the water condensation in the casing. The sand fluidization and the heat distribution were good and some improvements were made on the new burner tube coupling (which had been used already in the first test). A heat input of between 50,000 and 56,000 BTU/burner, hour, could be maintained. Some of the casings, however, burst very early and after two months' operation 11 of the 14 casings were damaged. This was attributed to weak welding seams, possibly in conjunction with lateral movements in the shale layers. The test had to be shut off by the end of May, 1960.

A third test, consisting of 5 burners, was started in September, 1960. The test was running until the end of November, 1960, when it had to be shut off because of the total shut-down of the Ljungstrom plant. Two casings failed during this period, but one could easily be repaired and restarted. The remaining burners ran smoothly and showed no corrosion at the inspection after the end of the test. Heat inputs of 50,000 - 56,000 BTU/burner, hour, were used and the highest temperatures observed in the temperature wells were about 400° F.

The test details are reported in the monthly reports. The final burner design, used in the third test, is shown on the drawing 159 - 39. The most important new experiences were the following.

1. Lighting (and relighting) of a burner could earlier be done only after pulling the burner tube above the sand filling. The new "burner tube coupling" made it possible to raise only the upper part of the burner during the lighting. When the flame has reached its position in the burner cone, the two burner parts are tightened against each other and locked in this position, whereby the flue gases are forced through the sand. No difficulties are encountered, when the burners are lit with this arrangement.

2. Condensation of water in the bottom of the casing during the initial operation results in the extinguishing of the flame. It was found that this can be avoided if the quantity of material, which should be heated above the condensation temperature, is kept as low as possible during the first period. Under the test conditions it was sufficient to run the burners with half of the normal sand quantity (which is about 20 feet) during the first 20 - 30 hours.

3. Condensation of water in the top of the casing in a later stage of the operation causes the formation of sand plugs, which prevent the even gas flow. One remedy is to blow out the water intermittently with air through a thin piece of pipe, inserted in the casing. More effective is, however, to raise the wall temperature of the casing by an increased heat input. Because of the low heat conductivity of the surrounding overburden layers, only a moderate increase is necessary. In the third test a heat input during the first 1,000 hours of 60,000 BTU/burner, hour, was used with success.

4. The problem of controlling the amount of sand was studied. In the Santa Cruz tests this was done by pulling the burner out of the sand. In the new test a rough check was obtainable by measuring the pressure drop through the burner. A more accurate check was obtained by lowering a piece of iron rod in a steel wire in the casing, while running the burner at a low heat input.

5. The sand erosion on the burner tube and the supply tube was a serious problem at Santa Cruz. In the new tests used burners from Santa Cruz

were used anew. All projecting construction details were eliminated (except - of course - the centralizing fins). After the tests the burners were inspected. The only wear that was detected was on the cone and on a few of the centralizers. Judging from the test experiences, the same burners can be used several times, if the cone is made of a high-heat-resistant alloy. Probably some of the centralizers must be replaced and the tightening surfaces on the burner tube coupling must be repolished between each operating period.

6. Burner casings of plain carbon steel seem to be usable even for prolonged heating, as long as good fluidization is maintained.

7. A 50 feet interval can be heated evenly, if a 33 feet long, 1-inch burner is used in a 3 1/2 inch casing with 15 - 20 feet of sand at heat inputs of 50,000 - 55,000 BTU/burner, hour.

January 28, 1967

SVENSKA SKIFFEROLJE AKTIEBOLAGET

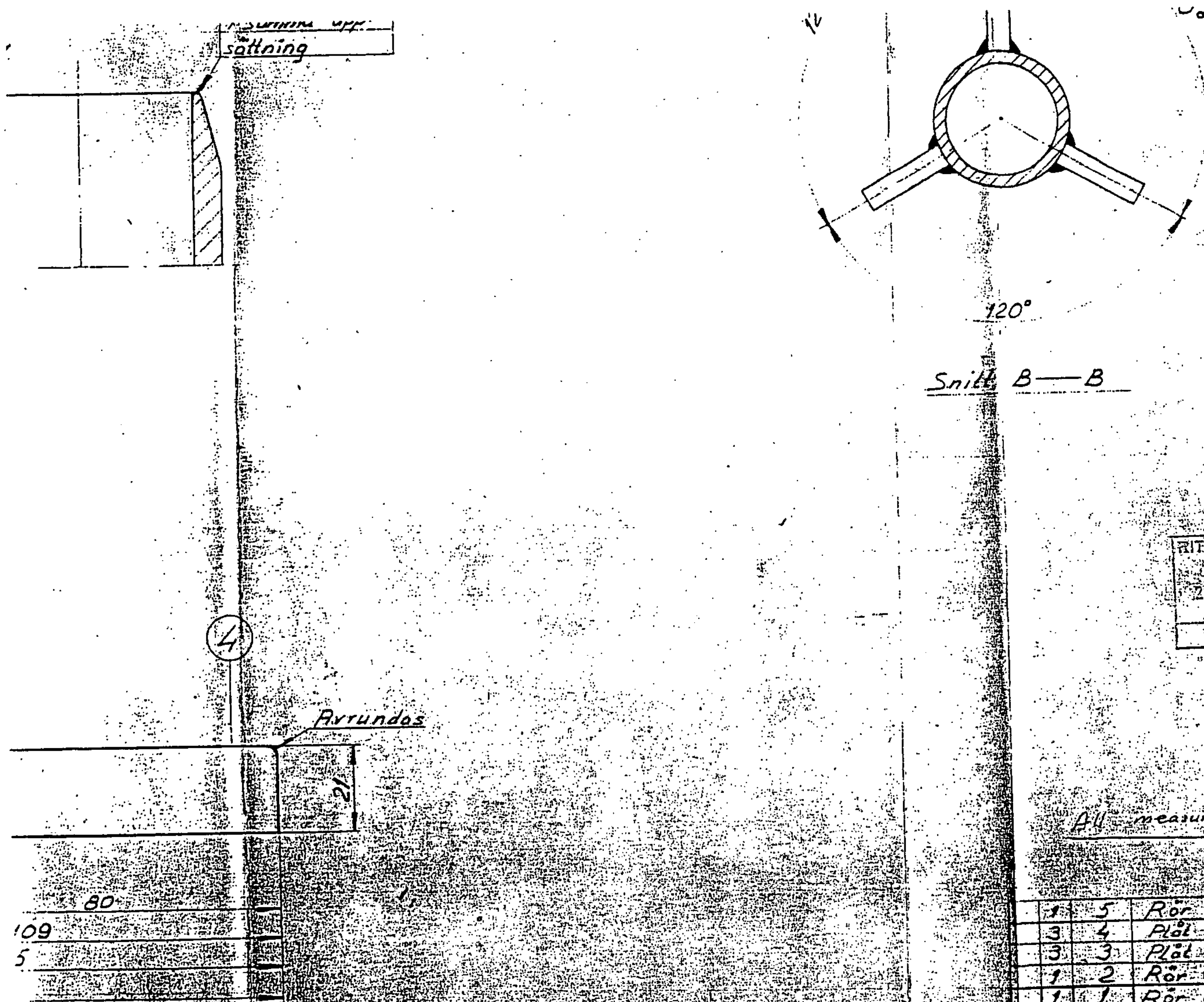
Gosta Salomonsson

Gosta Salomonsson

Bengt Persson

Bengt Persson

Appendix: drawing 159 - 39



RITKONTORET
25 JAN 1961
Sign.

All measures in millimeters (25.4 millimeter = 1 inch)

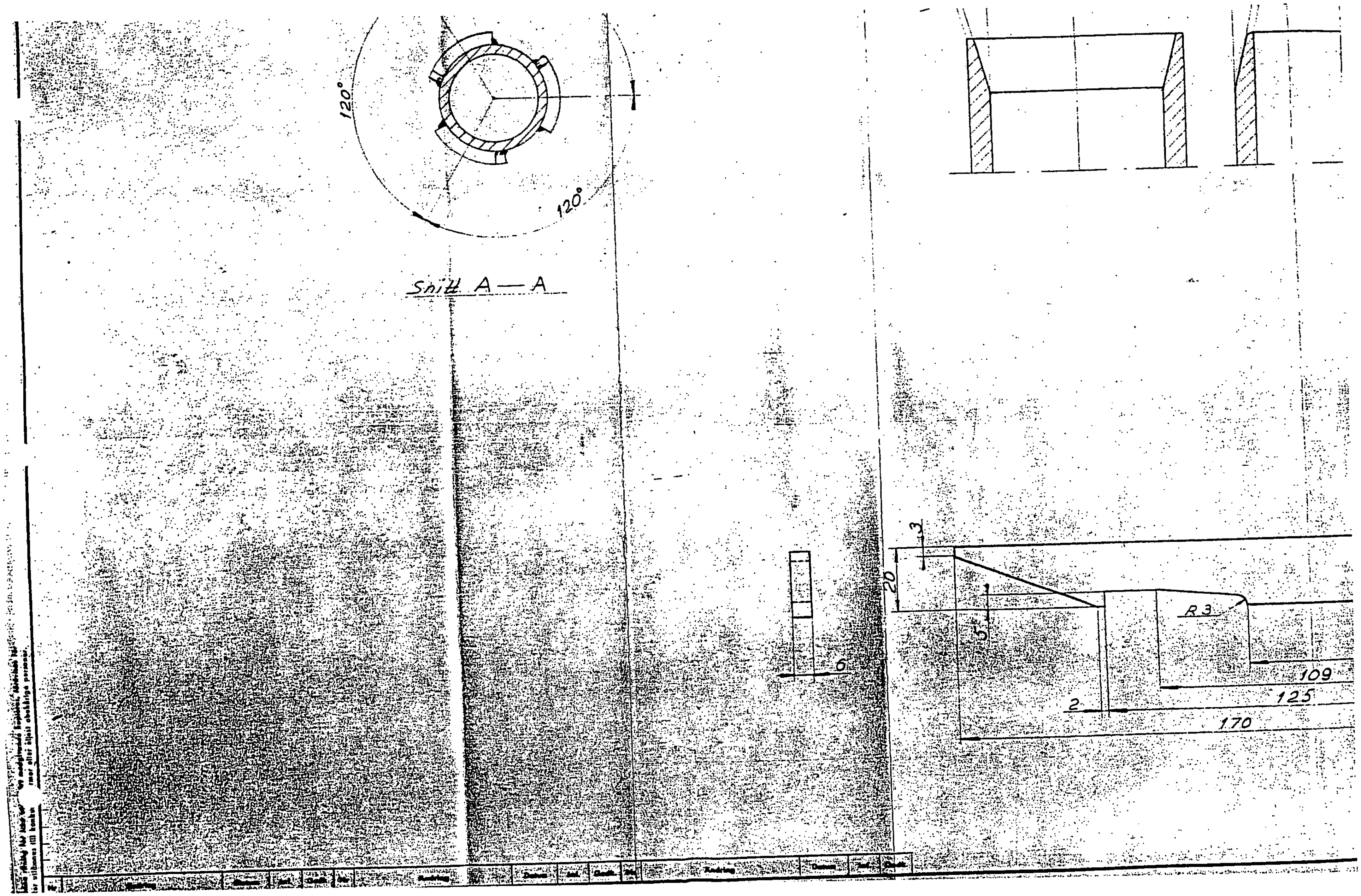
1	5	Rör	ø 25×2×1027	Stål 2930		(18/8 Steel)
3	4	Plåt	170×21×6	Stål 2930		(18/8 Steel)
3	3	Plåt	22×15×4	Stål 2330		(18/8 Steel)
1	2	Rör	ø 33,5×3,25×150	Stål 2330		(18/8 Steel)
1	1	Rör	ø 33,5×3,25×230	Stål 2330		(18/8 Steel)

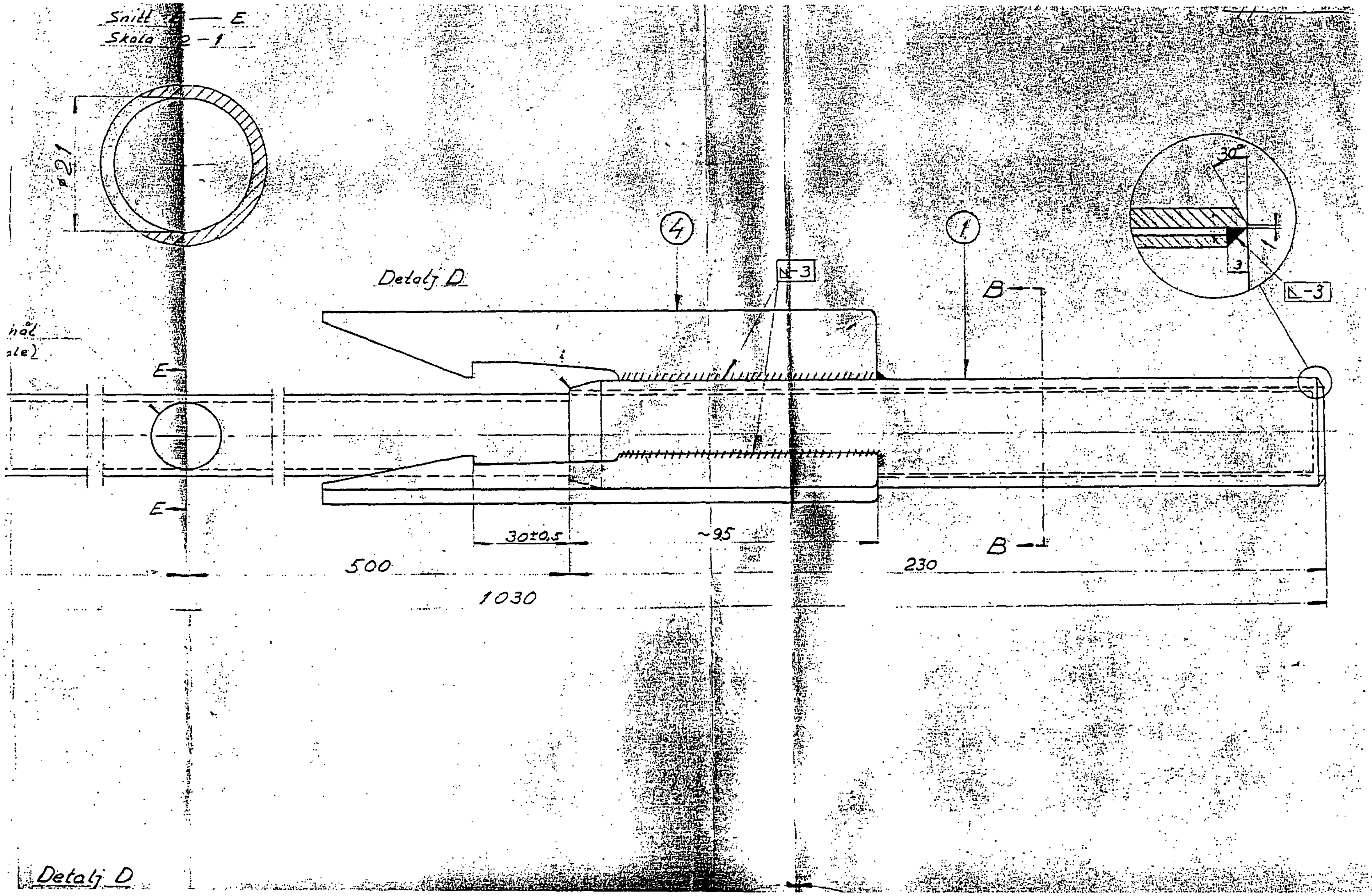
Lln		Led	25-1-61	1-1, 2-1	159-37

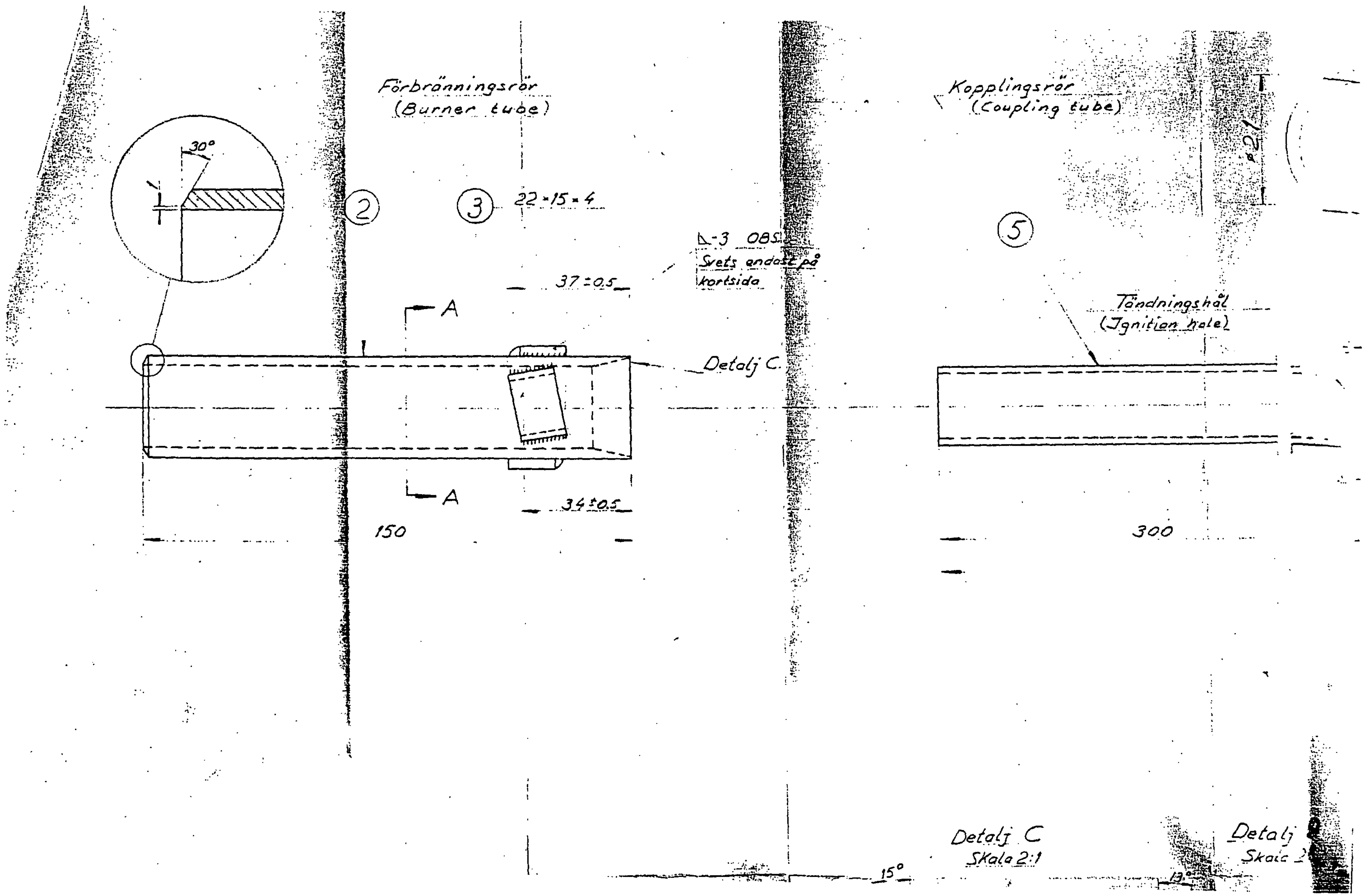
KL Gasbrännar försök

Brännarkoppling med kopplingsrör

159-39


120°
120°
Snitt A—A
3
20
5
6
R3
2
109
125
170


Snitt E — E
Skala 2 - 1
ø21
Detalj D
4
1
B
B
E
E
30°
3
-3
-3
30±0,5
~95
500
230
1030
Detalj D


Förbränningsrör
(Burner tube)
30°
2
3
22 × 15 × 4
37 ± 0.5
A
A
3.4 ± 0.5
150
Detalj C.
△-3 OBS!
Svets endast på
kortsida
Kopplingsrör
(Coupling tube)
5
⌀21
Tändningshål
(Ignition hole)
300
15°
Detalj C
Skala 2:1
13°
Detalj
Skala

Report LINS Burner Test "Gas-KL"

September through November, 1959

Summary

The burners have been in operation only 7 days since September 15th to December 1st with a total heat input of 5×10^6 BTU/burner (1300 Mcal/b). Great difficulties arose, mainly due to condensation of water in the bottom of the burner casing, which resulted in an uneven sand fluidization. It is now thought that the difficulties have been overcome by improved facilities for the fuel supply and an increase of the heat input. Two main experiencies have been made, namely that it is very important to remove all the water in the air line and also to have the orifice plates on the top of the supply tube. They should be placed as close as possible to the top of the burner casing so the exhaust gas can heat the orifice plates to avoid ice forming at the expansion of the gas.

A new burner device has been developed. To facilitate the lighting of the burner without pulling it out of the sand, a burner tube coupling has been designed. This functions so that part of the burner tube, which is above the sand can be separated from the remaining burner tube part and then pulled a couple of inches. After the burner has been lit, the burner parts can easily be sealed together by the burner tube coupling.

B 87 burner casing and cone has failed probably due to a bad cone.

B 89 and 91 casings have also failed due to an uneven heat distribution which probably was caused by ice plugs in the orifice plates.

1. Preparation

The fuel gas station was built and the burners installed according to the proposed test program with the following exceptions. No temperature recorders, only thermometers are installed in the air and gas lines. The burner casing diameter is 2.97 x 0.16 inches (75.5 x 4.0 mm) instead of 2.99 x 0.12 inches (76.0 x 3.0 mm). The actual fuel gas system is shown on Fig 1.

2. Operation and improvements in equipment during start up period, September 15 - December 1, 1959

The 10 burners were started September 15th. Each burner casing was filled with

19.5 feet (6 m) burner casing of sand (~ 26 feet annulus), while the burner was kept a couple of inches above the sand level in a mast. After the igniting, the burner was left to work itself down in the sand, while this was fluidized increasingly. The net heat input was about 32,000 BTU/burner-hour (8.0 Mcal/b-h).

The burners went out several times and were shut off after about two days, because of water collection in the casings. The water was partly moisture from the compressed air, which separated in the F-lines, and partly combustion water, which condensed in the cold burner casings. The sand became too wet and fluidized irregularly.

The cone and the burner casing in B 87 burned off, partly due to too low sand expansion but mainly due to an earlier damaged cone. (All the cones were used in L 9, Santa Cruz.)

Burner coupling

Before the burners were started again, efforts were made to find a method to light the burner without pulling it out of the sand. It was found that this can be done by cutting off the burner tube horizontally above the unexpanded sand level with a coupling between the parts which easily can be locked and unlocked by turning the supply tube. By this device it is enough to pull the upper burner part only a couple of inches for lighting. The burner tube coupling is shown on Fig 2. The end surfaces of the burner parts are ground conically in order to ensure a tight connection. The burner tube parts are held together by three centralizers, placed on the cone part with cutting-outs, fitting into three shoulders welded on the bottom part. Because the shoulders are placed in 10 degrees angle towards a plane perpendicular to the burner tube, the upper part can be pressed towards the bottom part by turning the supply tube above ground surface. The bottom part stands on the bottom of the burner casing with two iron "legs".

During the first operating period it was found that the sand fluidized too high. Therefore the sand level was decreased to 17 feet (5.2 m) annulus. The burner tube was shortened 4.0 feet (1.2 m) to 32 feet (9.8 m). All burners were then cut off 19.3 feet (6.0 m) from the bottom end, thus 2.7 feet (0.8 m) above the sand level. No couplings were arranged in this first change.

In order to facilitate the fluidization during the start-up period, the original sand was replaced by fine sand. The sieve analysis of the used sands and, as comparison, of the sand, used for L 9, Santa Cruz, are:

Size mm	Coarse sand %	Fine sand %	Sand in L 9 %
>2	0.6	0	0.7
1 - 2	93.0	31.5	91.9
0.5- 1	6.3	64.5	7.4
<0.5	0.1	4.0	0.03

When the condensation of the water ceases and the sand becomes dry, the loss of this fine sand will probably be too high. Therefore, coarse sand will be used to replace the lost sand.

Second start

The burners, except B 87, 90 and 94, were restarted October 10th with a net heat input of about 32,000 BTU/burner-hour. B 90 and B 94 could not be started, because it was discovered that water leaked into the burner casings, probably from the bottom. All burners were shut off after one day because of power failure. During the relighting after about 2 hours, it was found that too much water had condensed in the burner casings. Therefore, the burners had to be pulled in order to rinse out the sand with compressed air to get the casings dried. It was now discovered that the seal between the two burner tube parts had been somewhat damaged due to insufficient tighting and simultaneous erosion by fluidized sand. Because of this and also the difficulty in pulling the bottom part of the burner tube, the earlier mentioned shoulders and the corresponding cutting-outs on the centralizers were made.

It was also tried to tighten the leaking casings B 90 and B 94 and the burned off casing B 87 by injection of cement.

Third start

Table 1 gives the operation data for this period from November 10th to November 20th. The leaks in the casings B 87, B 90 and B 94 could finally be tightened, however for B 87 only for a short time. This burner was from November 19th definitely out of operation. Because part of the burner casings B 90 and 94 were filled with cement, these burners had to be placed 13 feet (4.0 m) higher than the other burners.

As seen from Table 1, there were three shut-downs, but the burners could easily be relit despite the casings contained some condensed water. It was easy to "unscrew" and pull the cone part at the relighting. However, after the last shut-down on November 20th the burners could not be separated, and thus the whole burners had to be pulled. It was found that the centralizers just below the cutting-outs had cut into the bottom burner part. This was easily corrected by grinding off the centralizers about 1/16 inch. The ground end surfaces on the burner parts were good except in B 89, where gas had leaked through and damaged not only the burner parts but also the casing.

The last shut-down was probably caused by ice plugs in the orifice plates. In any case the orifice unions became covered with ice. At the expansion of the gas through the orifices the gas is cooled, and when the outside temperature was only about 33° F, the condensed water froze here. Thus the air/gas flow continuously decreased. Simultaneously the pressure difference over the orifice plate increased, and at a low flow rate the ice plug was pushed away, and then the cycle could be repeated. Thus the orifice plates should be kept warm, and therefore they were moved from the 2-inch fuel-line to the top of the supply tube, where the exhaust gas could supply the necessary heat.

Unfortunately, two burner casings B 89 and 91 failed during the time when the ice forming was discovered. B 91 cone was badly corroded, which probably was due to such a low heat input during the ice forming that the sand did not fluidize up to the cone. In B 89 the flame had been at the burner tube coupling, which was completely destroyed.

Situation before fourth start

The test can continue with only seven burners because B 87, 89 and 91 have failed. The cones have been placed at 72 feet (22 m) from ground surface except in B 90 and 94 where the cones and the burners have been placed 13 feet (4.0 m) higher, thus at 59 feet from ground surface.

The burner tube coupling has been improved and is now tighter, but still easily separated.

To avoid water condensation in the burners, two water separators have been installed in the air line.

Fine sand will be used, and the burners will be run at a higher heat input than before.

The orifice plates have been moved to the top of the supply tube in order to heat the orifice plates to prevent plugging of these by ice.

The fuel gas station has been improved so a steady flow of air and gas will be obtained. A new stationary compressor instead of the mobile one will be installed.

Närkes Kvarntorp, December 16, 1959

Bengt Persson

(Bengt Persson)

Vidi /Sal

The l Method
Project Gas-KL
November 1959

le 1

Operation data during third start of Gas-KL

Net heat input: 32,000 BTU/burner-hour

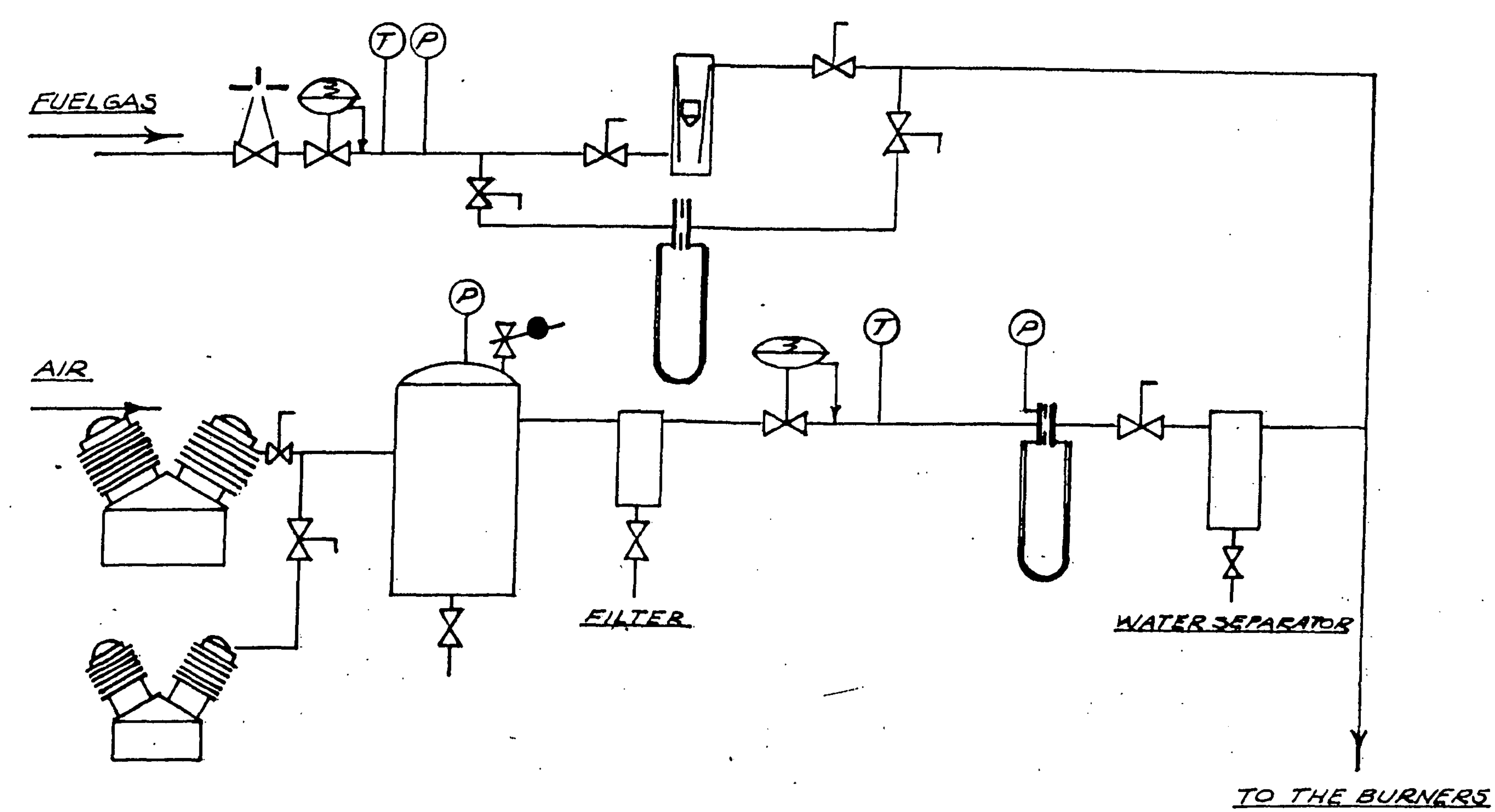
Date Nov. 1959	Time	B 87	B 88	B 89	B 90	B 91	B 92	B 93	B 94	B 95	B 96
10	10.00	Hole in cas.	On	On	Leak in cas.	On	On	On	Leak in cas.	On	Could separa b-tube
	22.00	All burners off due to water in F-line. Water separator was not drained.									
11	10.00		On	On		On	On	On		On	
	14.00										Burner On
	20.00			Off							
	24.00										Off
12	14.00	The low-pressure compressor shut off because it leaked oil.									
13	14.00	Mobile compressor installed. 3 more burners could be started.									
		Cas. cemented On							On		On
	22.00	Off				Off	Off	Off			
14	20.00	All burners off because of burner failure.									
15	16.00		On			On	On	On		On	On
	22.00	All burners off due to damage of packer in gas pressure regulator caused by oil in the gas.									
18	12.00	All burners on. Leaks in casings B 90 and 94 tightened by cement injection.									
19	02.00			Off							Off
	16.00			On							On
	24.00	Off Leak in cas.									
20	08.00	All burners except one off, because the orifice plates were plugged with ice.									

B 89 and 91 burner casings burned off. The seal in B 89 burner tube was damaged because the gas had burne here. B 91 cone was badly corroded. The sand had probably not fluidized because of the continuous decreas in the gas supply caused by the ice plug in the orifice.

Note: Hours between 0 and 12 are a.m., hours between 13 and 24 are p.m.

FUEL STATION FOR GAS KL.

7.12.1959 M.E.



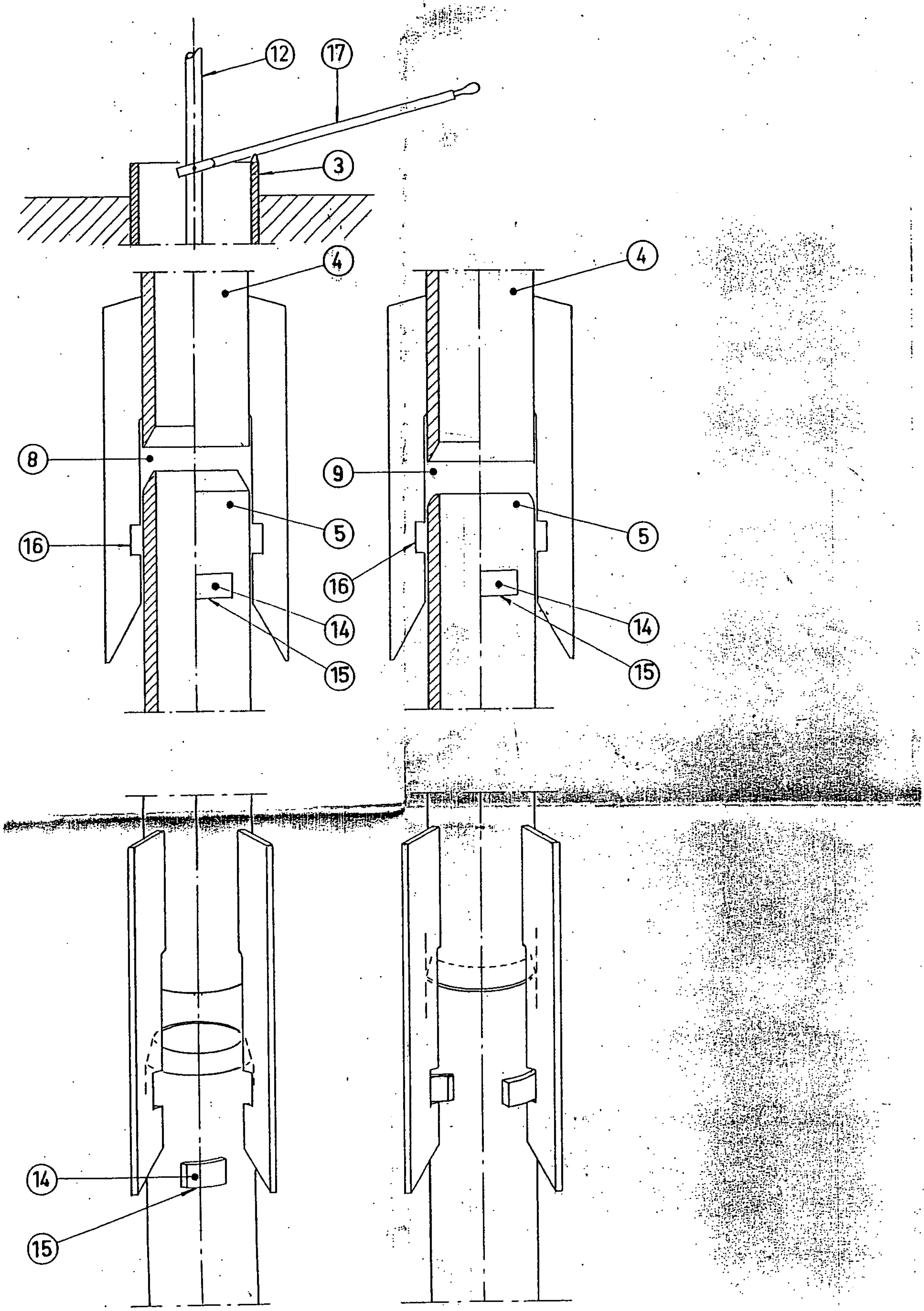

12
17
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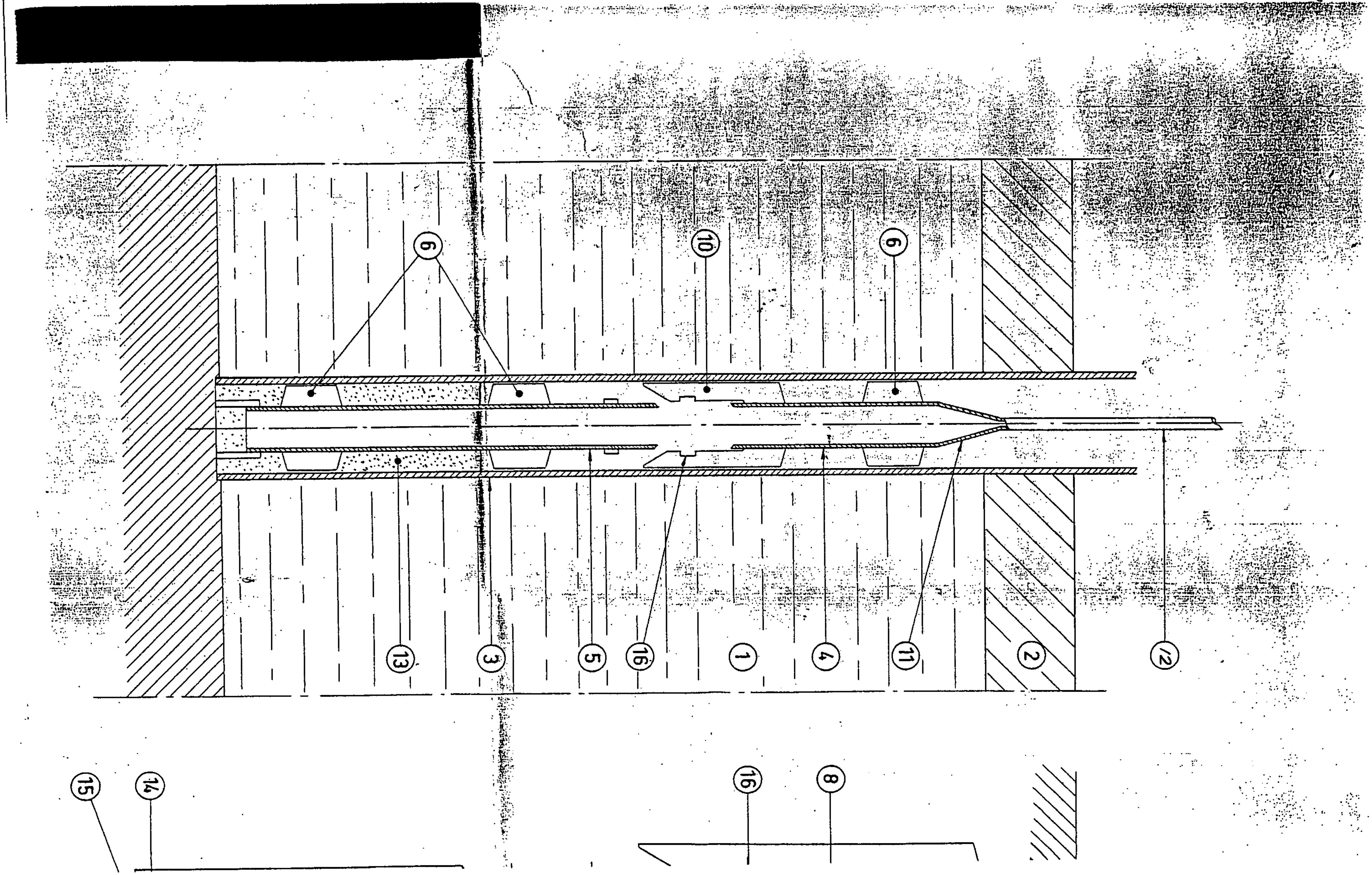
Fig. 2.



Report on LTNS Burner Test "Gas-XL"

December, 1959

Summary

The seven remaining burners were started December 2nd. Great difficulties with the condensation of the combustion water were soon encountered. Wet sand partially plugged the bottom of the burner tube, increased the pressure drop of the burner and resulted in flue gas leakage through the burner tube coupling. Herewith, the sand could not fluidize and did even collect more condensed water. This was probably the main reason for five casing failures. However, two of these failures occurred in B 90 and B 94, which had earlier been cemented to stop water leakage in the bottom of the casings. Probably these cement plugs did not hold for the heat. B 96 burner became stuck in the casing, and only one burner was in operation, when the test was shut off on December 20th.

Operation

The test was restarted December 2nd with the seven burners B 88, 90, 92, 93, 94, 95, 96, with those changes which were described in the former report.

The condensation of some of the combustion water in the lower part of the burner casing was soon encountered. Therefore, the net heat input was increased from 32,500 BTU/burner-hour (8.2 Mcal) to 35,000 BTU/burner-hour (8.8 Mcal) after 26 hours and to 40,000 BTU/burner-hour (10 Mcal) after another 23 hours, which input was maintained until the end of the test. However, the "water problem" continued, mainly because of leaking burner tube couplings.

It was discovered that the pressure drop of the burner sometimes was steady (instead of rippling) and higher than normally. This may be explained by a leaking burner tube coupling in combination with some sort of a plug of wet sand, which increased the pressure drop. When the gas leaked out through the coupling (above the top of the settled bed), no fluidization could occur. This was also proved by determining the top of the fluidized bed with a short ½" tube sunk down with a wire. No sand was found at the cone level, when the pressure was steady. (The sample tube could not be sunk down below the cone.) When the pressure drop varied in the range of 3 - 4 psig, the sand fluidized

and sand samples could be taken. Naturally, there could still be some leakage through the burner tube coupling. This was assumed to occur, particularly when the sand expansion (ratio of the heights of the fluidized and of the settled sand) was below 2.2.

When the burner tube couplings were put together in straight alignment above ground and tested with about 30 psig air pressure, only little leakage was found, but when the two burner parts were put together in a slight angle the leakage was large. This might have been the case, when the burner was down in the burner casing.

When the fluidization ceased and when there was water bubbling in the burner casing, the burner was shut off. Sometimes the sand could be dried by leaving the fuel gas-air mixture blowing through the burner over night. Sometimes it was enough to blow air through at a pressure of about 45 psig for a few seconds. Therefore, it was thought that in the bottom of the burner there was a plug of wet sand, which was released. Several times it was necessary to blow out all the sand and water with air and then pour in new sand.

The amount of sand was 16.5 feet annulus, which after 173 hours was increased to 19.0 - 19.7 feet annulus. The sand expansion was normally 2.3 to 2.4, occasionally as low as 2.2 or less or as high as 2.6 and 2.8. Even these values were lower than the expected expansion of about 3.0. However, the actual expansions were probably higher than those measured, because of some undetermined loss of sand.

The test was shut down after 432 hours on December 20th, when there was only one burner in operation. Five burner casings had failed and one burner was stuck in the burner casing.

The actual operation time and total heat input was:

	Hours in operation			Million BTU supplied		
	Until 12.2	12.2 - 12.20	Total	Until 12.2	12.2 - 12.20	Total
B 88	60	336	396	5,0	13,1	18,1
B 90	60	54	114	5,0	1,8	6,8
B 92	60	155	215	5,0	6,0	11,0
B 93	60	49	109	5,0	1,6	6,6
B 94	60	308	368	5,0	12,0	17,0
B 95	60	362	422	5,0	14,2	19,2
B 96	60	284	344	5,0	11,0	16,0

The history of the individual burners is given on Tables 1 through 7 and commented below.

B 88. After 124 hours the burner was off during 20 hours for water removal in the burner casing. It was then running allright, and the sand expansion increased from 2.2 to 2.8 until 308 hours, when all remaining four burners were shut off because of a ruptured air hose. Because of difficulties with B 94 and B 96, only B 88 and B 95 could be started again at 384 hours. Before the start a plug of wet sand in the bottom of B 88 had to be blown out with air. Thereafter the burner was running satisfactorily, despite a low sand expansion (2.1). Nevertheless, the burner casing burned off at 428 hours. The burner could easily be pulled and showed no sign of wear. The lower sand expansion after the last restart might have been due to some leakage through the burner tube coupling, which gave a distortion of the heat distribution with a subsequent overheating at the cone level.

B 90. The burner was shut off after 54 hours, when the water was bubbling in the burner casing, and the pressure drop became steady at 33.8 psig. It was found that the casing had burned off. When the burner was pulled, it was discovered that the threads on the 1/4" supply tube coupling 3 feet above cone were corroded off. As described in the last report, the bottom of the casing was cemented to stop leakage here. This seal did probably not hold, and thus water came up and made the sand too wet to fluidize. The pressure drop increased and the gas started to leak out through the coupling, which resulted in too high temperature at the cone level.

B 92. The sand did not fluidize and the burner casing collected too much water despite three attempts to blow it dry. At a fourth trial after 124 hours the burner tube coupling could not be separated. It was found that the coupling centralizers were bent, and the burner was replaced with another one. After it was restarted at 149 hours, the sand fluidized, but it still became wet, and the sand expansion was only 2.2. After another 17 hours the fluidization ceased completely. Several attempts were made to get the burner to work, but it did so only for short periods, and at 224 hours the burner casing and also the cone burned off. The burner tube could not be pulled. The failure must be assumed to have been caused by a leak in the burner tube coupling.

B 93. Despite the burner seemed to run satisfactorily with good fluidization, the burner casing burned off after only 49 hours. The burner was undamaged, and there was no indication of the cause of the failure.

B 94. The burner was in continous operation until 308 hours, when the test shut-down occurred due to the ruptured air hose. At the same time the burner casing burned off. The burner was undamaged, and the failure was probably in some way connected with the shut-down. It can be assumed that the cement plug in the bottom of the burner casing cracked at the rapid temperature decrease after the shut off. Except during the first 5 hours without fluidization, the operation of the burner did not give any trouble, and the sand expansion had started to increase above 2.4.

B 95. No difficulties arose until the restart after the common shut-down at 360 hours. The sand did not fluidize, therefore the burner was pulled, and the sand replaced. A plug of wet sand in the bottom of the burner tube was discovered, which must have been formed during the shut-down. After it was started again at 382 hours, the burner worked allright until the end of the test at 432 hours. During the operation, the burner went out two times, but was easily relit.

B 96. When the burner went out two times, the burner tube coupling could not be separated, and the whole burner had to be pulled both times. The coupling centralizers were too tight and had to be ground off somewhat. After the second start, the fluidization was hindered by a sand plug, but this was easily removed by a sudden shock of 50 psig air pressure. At 291 hours the burner was shut off in order to measure the height of the settled bed by sinking down a 1/4" pipe along the burner tube. Unfortunately the pipe was dropped, became stuck together with the burner, and could not be pulled. Therefore, the burner could not be started again.

Discussion of results

The removal of the combustion water in the burners was the main problem. This will probably be more accentuated the longer the burner casings and the burner tubes are. For a certain desired heated interval the burner tubes should be as short as possible and the heat input as high as possible, so that the bottom of the burner casing can rapidly be heated up to a temperature above the dew point of the flue gas.

For long burners it is necessary to have an arrangement, so that the burner can easily be pulled above the burner sand for relighting. This has been accomplished by pulling only that part of the burner which is above the sand. Therefore, a kind of a coupling on the burner tube has been tested. However,

the used coupling has to be improved, especially with regard to tightness against gas leaks. If part of the flue gas leaks out above the sand bed, the flow through the sand and thus also the degree of fluidization is decreased. This was probably the main reason for the casing failures.

Another reason for failure may be the heat expansion of the burner casing. This is packed firmly in the formation with sand, and thus the longitudinal thermal expansion of the casing is restricted. The obtained thermal stress may cause casing ruptures.

Outline for a new test

A new test of fifteen burners will be started in March 1960. A 3.50 x 0.13 inches (89 x 3.25 mm) burner casing will be used, whereby heat inputs of up to 55,000 BTU/burner-hour can be maintained. The length of the burner tube will be 33 feet, but one 29.5 feet and one 26 feet long burner tubes will also be tested. An improved burner coupling will be used. The used 1/4" supply tube, sch. 40, will be replaced by 3/8" tube, sch. 40, so that the burner can be easier turned to lock the burner tube coupling more steady. The fluidization will be controlled carefully. In three burners the temperature distribution will be checked with thermocouples in a 1" pipe, attached to the outside of the burner casing. To avoid thermal stress on the burner casings, these will be sand-packed only through the overburden and the limestone layers, and the holes will be drilled deeper than the casings, whereby these can expand downwards. Half of the casings will be supplied with 1.5 feet long expansion tubes, 4.01 x 0.14 inches. The casings will consist of carbon steel, but in half of them 6.5 feet of an alloy pipe will be used around the zone level. The holes will be drilled 1.5 feet from earlier set electrical heaters. These will be used as temperature wells, but in case of a burner failure the electrical element can be inserted and started to maintain the temperature in the formation.

Närkes Kvarntorp, March 15, 1960

Bengt Persson

(Bengt Persson)

Table 1

Jas-KL, B 38

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand: Settled bed A feet annulus	Sand: Fluidiz. bed B feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
									Cone at 72 feet.
2	10.00	0	On	16.5			22 - 25		Started with 32,500 net BTU/b-h (8.2 Mcal).
3	10.00	24					21 - 24		
	12.00	26							Heat input increased to 35,000 BTU/b-h (8.8 Mcal). Fluid. sa was too wet.
4	11.00	49							Heat input increased to 40,000 BTU/b-h (10 Mcal).
7	14.00	124	Off						Water in burner casing. Fuel air mixture left to blow thro to dry the sand.
8	10.00	144	On						40,000 BTU/b-h.
	16.00	150			36	2.2	25 - 28		Dry sand.
9	08.00	166					25 - 28	113	
	14.00	172					25 - 28		
	15.00	173		19.0					2.5 feet sand added.
10	08.00	190			43	2.3	25 - 27	133	Dry sand.
11	12.00	218			43	2.3	25 - 29	119	Dry sand.
14	13.00	291			53	2.8	24 - 28		Dry sand. Some loss of sand. 2.5 feet sand added.
15	06.00	308	Off						Air hose from mobile compressor ruptured. All burners off.
17	10.00	360	On				(7.3^x)		x) Without sand.
				16.0			26 - 29		
				19.7			27 - 30		3.7 feet sand added.
	14.00	364	Off						Remaining burner B 95 had to be shut off. Could not operate on one burner.

Table 1. !

Bas-KL, B 33

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand: Settled bed A feet annulus	Sand: Fluidiz. bed B feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
18	08.00	382					36.7		No fluidization, probably b[illegible] of plug of wet sand in burn[illegible] The gas leaked out through [illegible] tube coupling. Sand plug r[illegible] by a sudden shock of 45 psi[illegible] pressure. Some sand was lo[illegible]
	10.00	384	On	13.8 19.7			20 - 22 22 - 27		5.9 feet sand added.
	15.00	389			41	2.1			Dry sand.
20	06.00	428	Off						Burner casing burned off. [illegible] undamaged.

Table 2

Gas-KL, B 90

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand: Settled bed A feet annulus	Sand: Fluidiz. bed B feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
									Cone at 59 feet.
2	10.00	0	On	16.5			22 - 25		Started with 32,500 net BTU (8.2 Mcal).
3	10.00 12.00	24 26					21 - 24		Heat input increased to 35,[illegible] BTU/b-h (8.8 Mcal). Fluid. was too wet.
4	11.00	49							Heat input increased to 40,[illegible] BTU/b-h (10 Mcal). The san[illegible] still wet.
	16.00	54	Off				33.8		Too much water in burner ca[illegible] No fluidization. Fuel gas-[illegible] mixture left to blow throug[illegible] dry the sand.
5	10.00								Leak in burner casing. 1/4[illegible] tube threads at coupling, 3[illegible] above cone also corroded off burner undamaged.

Gas-KL, B 92

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand: Settled bed A feet annulus	Sand: Fluidiz. bed B feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
									Cone at 72 feet.
2	10.00	0	On	16.5			33.0		Started with 32,500 net BT (8.2 Mcal). No fluidizatic Orifice plate removed in or to increase heat input.
	15.00	5	Off						Water in burner casing. Bu pulled, sand and water blow and new sand added. Nothin wrong with the burner.
3	11.00	25	On						32,500 BTU/b-h.
	12.00	26							35,000 BTU/b-h (8.8 Mcal).
4	11.00	49							40,000 BTU/b-h (10 Mcal). sand still very wet.
	16.00	54	Off				33.8		Water in burner casing. Fue air mixture left to blow th
5	10.00	72	On				27.9		
7	14.00	124			36	2.2			Wet sand.
			Off						Water in burner casing. Fu air mixture left to blow th
8	10.00	144							Burner tube coupling could separated. Burner pulled. ling centralizers were bent. burner installed.
	15.00	149	On						
	16.00	150			34	2.1	25 - 28		Wet sand.

Table 3,

Gas-KL, B 92

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand		Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
				Settled bed A feet annulus	Fluidis. bed B feet annulus				
9	08.00	166					33.8	131	
	10.00	168	Off						No fluidization. Fuel gas-mixture left to blow througl
	14.00	172					28.7		
	15.00	173	On	19.0			25 - 28		2.5 feet sand added.
10	08.00	190					30.9	140	No fluidization.
11	11.00	217	Off				30.1		1/4" tube put down along bu tube to bottom of burner ca and air blown through. Stil the same pressure.
	12.00	218	On	19.7					0.7 feet sand added.
	13.00	219					30.9		
	14.00	220			39	2.0	25 - 28	133	Wet sand.
	18.00	224	Off						Burner casing and cone burnc Burner tube could not be pul

Table 4

Gas-KL, B 93

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand: Settled bed A feet annulus	Sand: Fluidiz. bed B feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
									Cone at 72 feet.
2	10.00	0	On	16.5			22 - 25		Started with 32,500 net BTU/ (8.2 Mcal).
3	10.00	24					21 - 24		
	12.00	26							35,000 BTU/b-h (8.8 Mcal).
4	11.00	49	Off						Burner casing burned off. B undamaged.

Table 5

Gas-KL, B 94

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand: Settled bed A feet annulus	Sand: Fluidiz. bed B feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
									Cone at 59 feet.
2	10.00	0	On	16.5			33.8		Started with 32,500 net BTU (8.2 Mcal).
	11.00	1							No fluidization. Heat inpu creased by removing of the fice plate.
	15.00	5					22 - 25		Orifice plate reinstalled. The sand fluidizes.
3	10.00	24					21 - 24		
	12.00	26							35,000 BTU/b-h (8.8 Mcal).
4	11.00	49							40,000 BTU/b-h (10 Mcal).
7	14.00	124			39	2.4			Sand was wet.
8	16.00	150			39	2.4	25 - 28		Sand was dry.
9	08.00	166					24 - 28	120	
	14.00	172					22 - 28		
	15.00	173		19.7					3.2 feet sand added.
10	08.00	190			43	2.2	22 - 27	130	Dry sand.
11	12.00	218			49	2.5	22 - 28	124	Wet sand.
14	13.00	291					21 - 27		Lost sand replaced with 2.5 sand.
15	06.00	308	Off						Air hose from mobile compres ruptured. All burners off. Burner casing burned off at same time. Burner undamaged

Gas-KL, B 95

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand: Settled bed A feet annulus	Sand: Fluidiz. bed B feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
									Cone at 72 feet.
2	10.00	0	On	16.5			22 - 25		Started with 32,500 net BTU (8.2 Mcal).
3	10.00	24					21 - 24		
	12.00	26							35,000 BTU/b-h (8.8 Mcal).
4	11.00	49							40,000 BTU/b-h (10 Mcal).
8	16.00				39	2.4	25 - 28		Wet sand.
9	08.00	166					22 - 27		
	10.00	168	Off						Burner went out. Easily rel
			On						
	14.00	172					22 - 28		
	15.00	173		19.7					3.2 feet sand added.
10	08.00	190			43	2.2	22 - 28	128	Dry sand.
11	12.00	218					24 - 29		
	14.00	220			43	2.2		126	Wet sand.
14	13.00	291					23 - 28		Lost sand replaced by 2.5 fe sand.
15	06.00	308	Off						Air hose from mobile compres ruptured. All burners off.
17	10.00	360	On				14.7		Without sand.
				15.8			36.7		No fluidization.
				19.4			36.7		3.6 feet sand added. Still fluidization.
	14.00	364	Off						No change. Burner pulled.

Table 6,

Gas-KL, B 95

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand Settled bed A feet annulus	Sand Fluidiz. bed B feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
18	08.00	382	On	19.0			26 - 29		Burner was all right but th a plug of wet sand in botto burner tube. New sand.
	15.00	389			43	2.3			Dry sand.
	16.00	390	Off On						Burner went out. Easily re
20	10.00	432	Off						Shut off.

Table 7

Gas-KL, B 96

Date Dec. 1959	Time	Hours from start	Burner off or on	Sand Settled bed A feet annulus	Sand Fluidiz. bed feet annulus	Sand Expansion B/A	Pressure psig	Temp., exhaust gas °F	Remarks
									Cone at 72 feet.
2	10.00	0	On	16.5			22 - 25		Started with 32,500 net BTU (8.2 Mcal).
3	10.00	24					21 - 24		
	12.00	26							35,000 BTU/b-h (8.8 Mcal).
4	11.00	49							40,000 BTU/b-h (10 Mcal).
7	14.00	124			43	2.6			Wet sand.
8	14.00	148	Off						Burner went out. Burner tu coupling could not be unscr Burner pulled. Centralizer low shoulders on coupling g somewhat.
	15.00	149	On						
	16.00	150			40	2.4	25 - 28		Dry sand.
9	08.00	166					26 - 29		
	10.00	168	Off						Gas mixture out of control. not separate burner tube co Burner pulled. Centralizers
	14.00	172	On	17.7			32.4		Sand plug released by air pr
	15.00	173					25 - 28		
10	08.00	190			40	2.3	25 - 28	126	Dry sand.
11	12.00	218					26 - 29		
	14.00	220			43	2.4		135	Wet sand.
14	13.00	291	Off						Burner was shut off to measu settled bed by sinking down pipe along burner tube. How the pipe was dropped, got st and could not be pulled.

Report on LINS Burner Test "Gas-KL"

January - February, 1960

Summary

After the test was shut off last month the undamaged burners were recovered. The damaged burners were inspected. A new test unit was prepared including 15 burner wells instead of the 10 used in the first unit. The new test site is chosen so that the gas heated area will be heated during the same period as the surrounding area is heated electrically.

In addition new air compressors were installed and the distribution system was adjusted.

A detailed description of the new wells will be given in the March Report. The burners will be started during the month of March.

Närkes Kvarntorp, March 25, 1960

Gösta Salomonsson

(Gösta Salomonsson)

Report on LINS Burner Test

Gas-KL 2

March, 1960

Summary

A new test field of 14 sandburners was built from January 15th to March 21st. The test is called Gas-KL 2. The main deviations from the first Gas-KL test are:

1. Larger burner casings with an inside diameter of 3.24" which will allow net heat inputs of up to about 14 Mcal per burner-hour (56,000 BTU/b-h).

2. In 8 burners 2 m (6'7") of the burner casing at the cone level is made of 18/8 stainless steel.

3. 9 burner casings sandpacked to only about half the depth from ground surface with 0.5 to 1.0 m (1'8" to 3'3") of open hole space below the bottom of the casing to allow downward expansion.

4. To avoid random effects the test area was chosen in the electrically heated Ljungstrom field and thus on all sides surrounded by electrical heaters. In case of a burner failure the corresponding temperature well can be converted to an electrical heater, whereby the heat supply to the formation can be maintained.

A few fluidization and igniting tests were run.

All burners will be started April 2nd.

Test arrangement

Hole pattern

The new test area is about 30 m (100 feet) from the first Gas-KL test within the Ljungstrom field. In order to avoid effects from the field edge (lower temperatures, movements in the shale layers) on the burners, they are placed 10 to 17.6 m (33 - 58 feet) from the field edge and

"protected" from the edge by 5 electrical heaters in each row. The test consists of 15 burners, placed in three rows with 5 burners in each. In this way all the burners will be tested for "inside" conditions.

The burner holes are drilled about 0.5 m (1'8") from the earlier set casings for electrical heaters, which instead will be used as temperature wells. In case of a burner failure the corresponding electrical heater will be reinstalled, so that the ordinary amount of heat can be supplied to the formation, and the remaining burners can operate under ordinary field conditions. Three additional temperature wells are also installed along the side of three burner casings, where the temperature will be measured by thermocouples.

The hole pattern of Gas-KL 2 is shown on Fig. 1. The burners and the temperature wells are numbered 1 through 15 with the prefixes B for burner and T for temperature well. The three temperature wells in the burner hole are also given a suffix B, for instance T 4 B. The electrical heaters have their regular field numbers, e.g. the 95th heater in the 88th row is numbered 88/95.

There is no B 1 burner and no T 1 and T 5 temperature wells. While being installed in the casing, the burner tube in B 1 was dropped and knocked out the bottom plate of the casing. An unsuccessful attempt was made to plug the casing with cement. Therefore, T 1 was converted to electrical heater 88/91. T 5 casing was hit by the drill bit and damaged, when B 5 was drilled. Therefore, T 5 had to be abandoned and plugged, and a new hole for B 5 was drilled on the opposite side of T 5. In order not to have B 4 too close to B 5, the place for B 4 also was changed.

Burners

In the previous Gas-KL test all the burner casings were sandpacked all way down to the bottom of the drillholes. Because only part of each casing was heated to high temperature and because of irregular formation movements due to thermal expansion, the casing failures might have been caused by an extraordinary bending of the casings. The burner holes in L 9, Santa Cruz, were drilled about 3 feet deeper and packed through the overburden only, around its concentric gas well. Thus, the burner casing was hanging free in the burner hole and could expand downwards. Because

of the good results obtained in L 9, it was decided to test similar arrangements in Gas-KL 2. Therefore, the burner holes are drilled 0.5 m to 1.0 m (1'8" to 3'3") deeper than the casings. Concentric gas wells are not used but all casings are packed to half the depth through the overburden layers. It was suggested that an expansion tube should be inserted around the bottom of some of the burner casings but the diameter of the bore holes did not permit this.

It was also decided to use 2 m (6'7") of an alloy of about the same quality (with 5 % Cr, 1.5 % Si, 0.5 % Mo) as used in L 9, Santa Cruz, on the burner casing at the cone level. However, 18/8 stainless steel was used, because this was the only quality available.

The place and the description of the final casing completions are shown on Fig. 1. Six burner casings are made of carbon steel (group I) and eight are made of carbon steel, except for 2 m (6'7") made of 18/8 stainless steel, at the cone level (group II). Each quality group is divided into three subgroups 1, 2 and 3 according to the depth of the drill hole and the sandpacking. The type 1 has the hole drilled to 32.5 m (106'8"), which is 0.5 m (1'8") below the bottom of the casing, and the casing sandpacked down to 16 m (52'6"). The type 2 has 33 m (108'3") deep holes thus 1.0 m (3'3") below the bottom of the casing. It is separated into 2 a with sandpacking to 16 m (52'6") and 2 b with sandpacking to 12 m (39'5"). The tree burners with the temperature well in the burner hole belong to group 2 b. It was originally planned to have the sand packed to 16 m for these also, but it was feared that it would be difficult to get the more complicated packer down to this depth, therefore, it was placed 4.0 m (13'1") higher up. However, it is doubtful if the sand was stopped on the packer for B 9 and B 14, because three times as much sand was used as for B 4. Type 3 has the casings packed all way down to the bottom. There are four burners in group 1 and five burners in each group 2 and 3.

The burner holes were drilled with a 110 mm (4.34") bit except for the type 2 b, where a 135 mm (5.31") bit was used. The dimension of the burner casings are 89 x 3.25 mm (3.50" x 0.13"). The temperature well in type 2 b consists of 1" pipe, sch. 40, and is welded to the burner casing with several 0.5 m long 1/2" x 1/8" carbon steel plates.

The casings were welded of 5 - 6 m (17' - 20') long joints. Each weld was tested with air.

Schematic drawings of the types I, 1 and I, 2 b are shown on Fig. 2 and 3 resp.

The length of the burner tubes is 10.0 m (32'10"), except in B 9 where it is 9.0 m (29'6") and in B 14 where it is 8.0 m (26'3"). They are made of 1" pipes, sch. 40, of the following qualities, counted from the cone, downwards:

25/20 stainless steel	1.2 m	(3'11")	1.2 m	(3'11")	1.2 m	(3'11")
18/8 " "	3.95	(13' 0")	3.95	(13' 0")	4.55	(14'11")
Carbon steel	2.85	(9' 4")	3.85	(12' 7")	4.25	(14' 0")
Total length of burner tube	8.00	(26' 3")	9.00	(29' 6")	10.00	(32'10")

The burner tube coupling, which is shown on Fig. 4, was placed at 3 m (9'10") below the cone on the 10 m (32'10") long burner tubes and at 2 m (6'7") below the cones on the shorter burner tubes. All the parts are made of 18/8 stainless steel. It was found that a thin layer of an "Anti-scuffing paste" on the conical ground parts makes the coupling almost completely tight. The main component of the paste is molybdenum sulphide with a melting point of 1.185°C (2.165°F). It starts to oxidize at about 600°C (1.100°F). However, it was found to tighten well, even when it was heated to about 800°C (1.500°F).

The centralizers on the burner tube coupling are made of 6 mm (0.23") thick 18/8 stainless steel plate. The centralizers, which are welded on the stainless part of the burner tube and supply tube, are made of 4 mm (0.16") thick 18/8 stainless steel. They are 150 mm (6") long and 21 mm (0.83") and 31 mm (1.22") wide, leaving a free distance of 3.5 mm (0.14") to the casing well. The centralizers on the carbon steel parts of the burner tube are 75 mm (3") long and 21 mm (0.85") wide and made of 3 mm (0.12") thick carbon steel plate. The centralizers are placed at the following levels counted from the bottom of the cone.

		10 m		9 m		8 m burner tube	
Above cone:		0.4 m	(1´ 4")	0.4 m	(1´ 4")	0.4 m	(1´ 4")
Below cone:	18/8 steel	1.5	(4´11")	1.0	(3´ 3")	1.0	(3´ 3")
	burner tube coupling	3.0	(9´10")	2.0	(6´ 7")	2.0	(6´ 7")
	18/8 steel	3.2	(10´ 6")	2.2	(1´ 3")	2.2	(7´ 3")
	-"-	4.0	(13´ 1")	3.0	(9´10")	3.0	(9´10")
	carbon steel	6.5	(21´ 4")	5.5	(18´ 0")	5.0	(16´ 5")
	" "	9.0	(29´ 6")	8.0	(26´ 3")	7.0	(23´ 0")

The centralizers at 3.2 and 2.2 m resp. were put on later, when it was found that those placed at 4.0 and 3.0 m were placed too far from the burner tube coupling. It happened that the bottom part of the burner tube came so close to the casing that the top part could not be screwed on.

The two so called burner tube legs were made of hard carbon steel, 8" x 1/2" x 1/2", welded to the burner tube, reaching 150 mm (6") below its lower end.

The <u>supply tube</u> is made of 0.8 m (2´7") 1/4" sch. 80 pipe, 5.0 m (16´5") 3/8" sch. 40 pipe and 16.5 to 18.5 m (54´ to 61´) 1/2" sch. 40 pipe. The 1/4" and 3/8" pipes are of 18/8 stainless steel and the 1/2" pipes of carbon steel.

The bottom of the one-joint 3/8" pipe is connected to the 1/4" pipe with a 1/4" coupling of stainless steel, welded to the 3/8" pipe and turned down to the same outside diameter as this. The top of the 3/8" pipe is welded to the 1/2" pipe with a 1/2" coupling 0.5 m (1´8") above this weld. By this arrangement, there is no projecting part that can be eroded away by the sand between the cone and the 1/2" coupling 6.3 m (20´8") above the cone with the exception of the centralizers. In the previous tests, when a 1/4" coupling was used between two 1/4" joints severe sand erosion was observed on the supply tube at the coupling. The 3/8" supply tube makes also the burner more rigid, so the burner tube coupling can easier be locked and unlocked. The 1/4" supply tubes, the cones and the stainless steel parts of the burner tubes were made from burners used in L 9, Santa Cruz.

Fluidization tests

Tests were run in five burners in order to determine the pressure drop through sand heights of up to 6 m annulus burner casing and burner tube at air flow rates, corresponding to 11, 12, 13 and 14 Mcal per burner hour (44,000, 48,000, 52,000 and 56,000 BTU/b-h). The results are shown on Fig. 5 as pressure drop versus sand height for different air rates. For comparison, the fluidization results with air in Well 120, Santa Cruz, are also shown, where the outside diameter of the burner tube was 1.66" and the inside diameter of the burner casing was 3.07". The pressure drop for more than 3 m (10') sand can be approximated to straight lines. The pressure drop was found to be 0.018 kg/cm^2 per meter sand height (0.79 psi/ft). According to the results in Well 120 it should have been 0.016 kg/cm^2, m (0.70 psi/ft), when it was calculated from the following formula:

$$\frac{\Delta P}{L_s} = 2.73 - k \cdot r_H$$

ΔP = pressure drop in psi

L_s = sand height in feet annulus

$r_H = \frac{D_c - D_B}{4}$ = hydraulic radius

D_c = inside diameter of casing in inches

D_B = outside diameter of burner tube in inches

k = a constant

From the fluidization tests in Well 120 k was calculated to 4.24. When expressing $\frac{\Delta P}{L_s}$ in kg/cm^2, m the formula is thus

$$\frac{\Delta P}{L_s} = 0.23 \left(2.73 - 4.24 \cdot \frac{D_c - D_B}{4}\right)$$

The difference between found and calculated pressure drops for the Gas-KL 2 burners lies within the error range. The results also showed that the pressure drop was independent of the used air rates which means that the fluidization point had been reached.

During these tests two kinds of sand were used, one hard and of a high

quartz purity from Simrishamn (called S 9) and one with a mixture of soft and hard minerals, also used for the packing of the casings (called P). The sieve analyses were:

Size mesh	Size mm	S 9 sand	P sand
> 10	> 2	7.2 %	0.7 %
10 - 18	1 - 2	41.9	35.6
18 - 35	0.5 - 1	26.8	13.6
< 35	< 0.5	24.1	< 0.1
Average particle size,	mm	1.082	1.404
	inch	0.0425	0.0553

The level of the top of the fluidized bed was also determined by sinking down a 150 mm (6") long 1/2" test tube in a wire. With 5 m (16'5") sand the tube was hit very weakly at the cone level only at the air rate, corresponding to 14 Mcal per burner hour (56,000 BTU/b-h). With 6 m (19'8") sand filling the sand fluidized well above the cone. The results are shown on Table 1. 2 to 6 m (6'7" to 19'8") of S 9 sand was used with 4 to 0 m (13'1" to 0) P sand above the S 9 sand. A combination of 2 m S sand or less in the bottom and P sand on top thereof did not function, because the fine P sand particles clogged the bottom of the burner tube, caused by the moisture in the used air and some collected water in the cold burner casings.

The tests showed that the sand expansion increased with the air rate and that the different sand mixtures gave about the same sand expansion except for 4 m (13'1") S 9 sand and 2 m (6'7") P sand, which gave a considerably higher value.

The pressure during the tests varied in ranges of from 0.02 to 0.15 kg/cm^2 usually, with increasing pressure variation for increasing amounts of sand, increasing contents of P sand and increasing flow rates. The pressure variations are shown on Table 2.

According to the above results a sand mixture of 4 m (13'1") S 9 sand and

2 m (6'7") P sand should give the best fluidization. Therefore, most of the burners were filled with this sand mixture but even other sand mixtures were tried. This is shown on Table 3 together with the measured sand expansion and pressure drop. These tests gave somewhat different results than the previous ones. With some exemptions they showed an increasing sand expansion for increasing amounts of P sand.

The obtained values of the sand bed expansion varied from 1.75 to 2.15. These values are much lower than expected. However, it is not known how the bed expansion with cold air can be compared to the same with hot flue gases. According to the equation for the calculation of the bed expansion, derived from the sandburner tests in Santa Cruz, the bed expansion for the Gas-KL 2 burners with 14 Mcal/b-h (56,000 BTU/b-h) and 6 m (19'8") sand should be as high as 4.02 ± 0.28.

Lighting tests

The fuel was the same kind of gas as used in the previous Gas-KL test. It was determined that the burner was easiest lit with 8 - 16 % air surplus above the stoichiometric mixture. At lower air contents the flame velocity was so high, that the gas mixture almost exploded in the burner tube, when the flame came into the tube. At air contents of more than 116 % and less than 68 % of the theoretical the flame velocity was too low.

It was intended to start the burner with the casings filled with 6 m annulus of sand. However, after the burner was lit and the burner tube coupling was locked, it was impossible to get the exhaust gas through the sand. By starting the burner against different amounts of sand it was found, that generally it could get started against not more than 3 m (10') sand. It was also found that the sand easily plugged the bottom of the burner tube, if the burner tube coupling was unscrewed with gas on. This caused a sudden pressure drop in the burner tube and the sand fell down immediately, and was partly pressed up in the bottom of the burner tube. To avoid tight-packing of the sand the gas supply must thus be shut off slowly, before the burner tube coupling is unscrewed.

An attempt was also made to stop the plugging of the burner tube by installing a 300 mm (1') long 2" socktube (tested in L 3, Santa Cruz) and a 30 mesh wire screen in the annulus between this and the burner tube. It did not work, because the wet sand plugged most of the screen openings.

Närkes Kvarntorp, July 29, 1960

Bengt Persson

(Bengt Persson)

Table 1

Fluidization tests in Gas-KL 2 burners with air

A. Sand expansion

Height of sand, meter annulus			Air rate corresp. to net Mcal/b-h	Sand expansion	
S 9 sand	P sand	Total		Height of fluid. bed A meter	$\frac{A}{6}$
6	0	6	12	< 10.0	< 1.67
			13	10.2	1.70
			14	10.7	1.78
5	1	6	12	10.0	1.67
			13	10.7	1.78
			14	10.7	1.78
4	2	6	12	11.7	1.95
			13	12.2	2.04
			14	13.2	2.20
3	3	6	12	10.7	1.78
			13	11.0	1.83
			14	10.8	1.80
2	4	6	12	10.0	1.67
			13	10.3	1.72
			14	11.3	1.79

Table 2

Fluidization tests in Gas-KL 2 burners with air

B. Pressure variations

Height of sand, meter annulus S 9 sand	P sand	Total	Air rate, corresp. to net Mcal/b-h	Pressure difference between max. and min. kg/cm^2
4	0	4	12	0.02
3	1			.03
2	2			.07
4	0	4	13	.02
3	1			.02
2	2			.08
4	0	4	14	.06
3	1			.05
2	2			.15
5	0	5	12	.02
4	1			.05
3	2			.04
2	3			.10
5	0	5	13	.05
4	1			.15
3	2			.10
2	3			.10
5	0	5	14	.04
4	1			.10
3	2			.05
2	3			.15
6	0	6	12	.02
5	1			.10
4	2			.10
3	3			.06
2	4			.10
6	0	6	13	.04
5	1			.02
4	2			.07
3	3			.15
2	4			.08
6	0	6	14	.02
5	1			.02
4	2			.07
3	3			.10
2	4			.13

Table 3

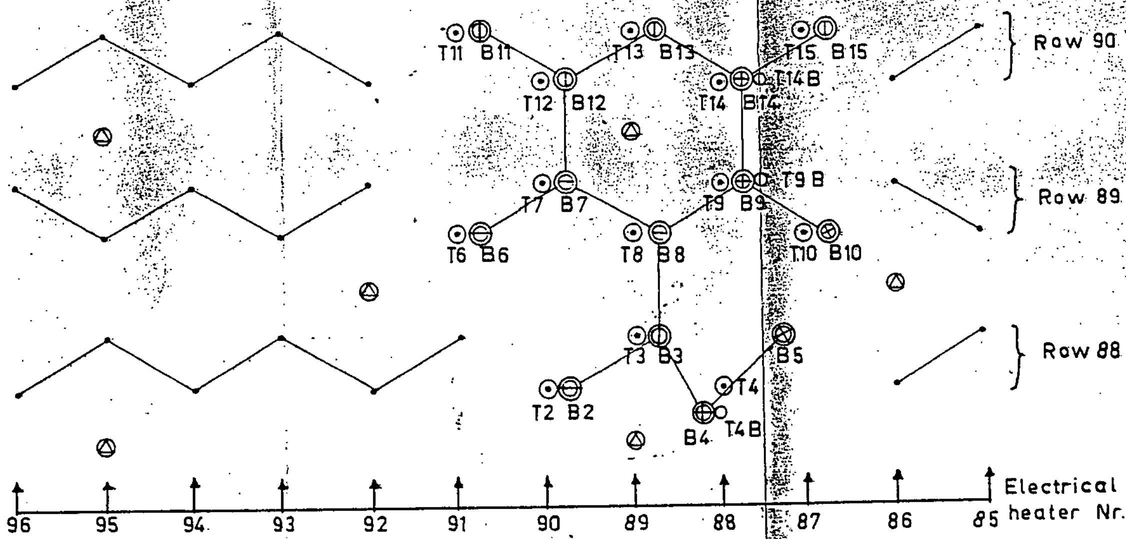
Fluidization tests in Gas-KL 2 burners with air

C. Sand expansion and pressure variations at a constant air rate, corresp. to 14 Mcal/b-h

Burner No.	Height of sand, meter annulus: S 9 sand	P sand	Total	Pressure variation kg/cm^2	Sand expansion: Height of fluid. bed A meter		$\frac{A}{6}$	
4	6	0	6	0.10	10.7	10.6	1.78	1.77
5				"	10.5		1.75	
3	5	1	6	0.10	11.5	11.8	1.92	1.96
15				0.20	12.0		2.00	
7	4	2	6	0.10	11.5		1.92	
8				"	11.5		1.92	
9				0.20	11.7	11.8	1.95	1.96
10				"	12.5		2.08	
14				"	11.7		1.95	
12	3	3	6	0.20	12.9	12.2	2.15	2.04
13				0.15	11.5		1.92	
11	2	4	6	0.20		12.3		2.05

FP/Emm
26.7. 1960.

Location: Section 8 of field KL-5

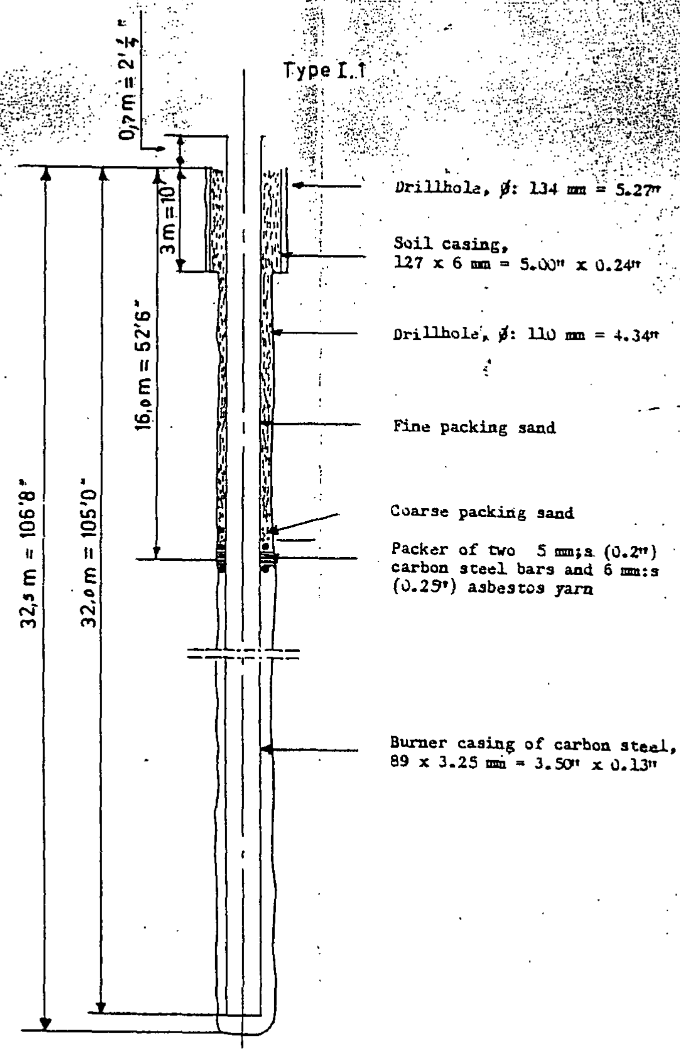


<u>Symbol explanation to Fig. 1.</u>

Symbol	Burner		Drill hole depth		Place of packer from ground surface		Burner casing
	Type	Nr	meter	feet,inches	meter	feet,inches	Quality
⊖	I, 1	2,6	32,5	106'8"	16	52'6"	Carbon steel
⊗	I, 2 a	5	33	108'3"	16	52'6"	– " –
⊕	I, 2 b	4	33	108'3"	12	39'5"	– " –
⦶	I, 3	3,11	32,5–33	106'8" – 108'3"	None		– " –
⊖	II, 1	7,8	32,5	106'8"	16	52'6"	Carbon steel + 2 meter 18/8 st steel
⊗	II, 2 a	10	33	108'3"	16	52'6"	– " –
⊕	II, 2 b	9,14	33	108'3"	12	39'5"	– " –
⦶	II, 3	12,13,15	32,5–33	106'8" – 108'3"	None		– " –

•	Electrical heater
⊙	Temperature well 0,5 meter (1'8") outside burner
○	" " alongside burner casing
⊗	Gas well

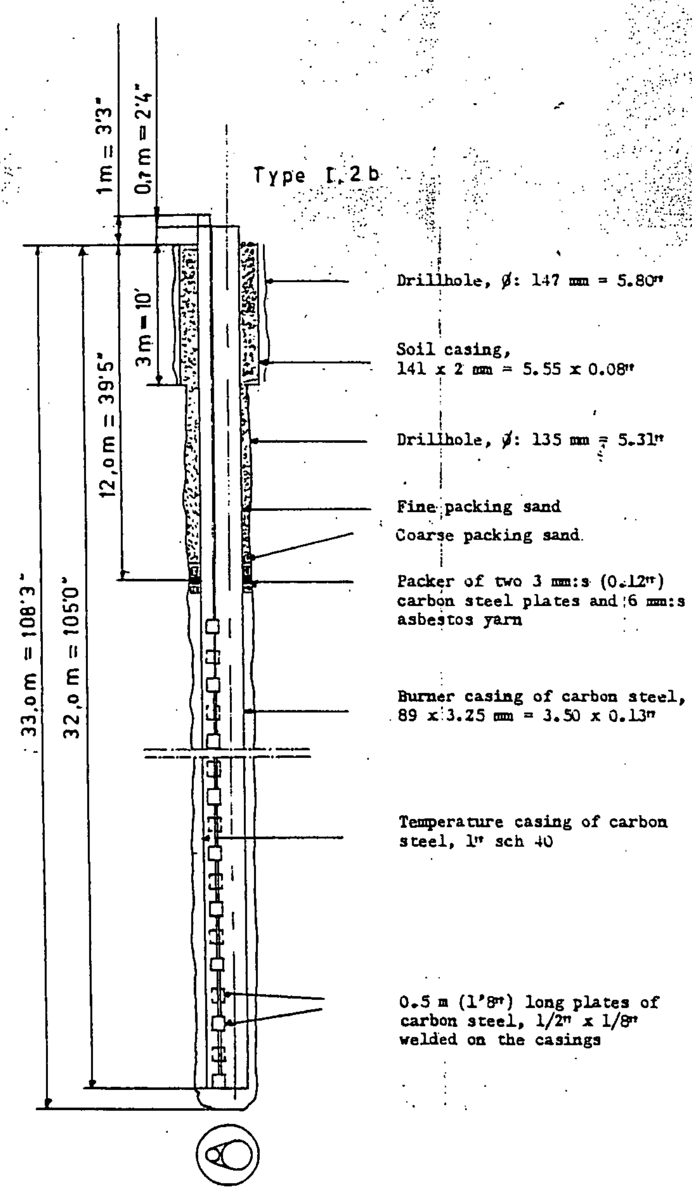
SVENSKA SKIFFEROLJE AB	Fastställd	Datum 19.5.60	Upplaga	Ersätter / Ersättes av	3 St



TYPE	DRILL HOLE, DEPTH m	feet, inches	OTHER CHANGES FROM TYPE 1
I, 2 a	33,0	108'3"	
I, 3	32,5 – 33,0	106'8" – 108'3"	No packer. Packing Sand to bottom
II, 1			2,0 m (6'7") of 18/8 stainless steel burner casing, 89 x 3.25 mm (3.50" x 0.13"), placed at 8.7 – 10.7 m (28'7" – 35'2") from bottom of casing.
II, 2 a	33,0	108'3"	The same as in type II,1.
II, 3	32,5 – 33,0	106'8" – 108'3"	The same as in type II,1. No packer. Packing sand to bottom.

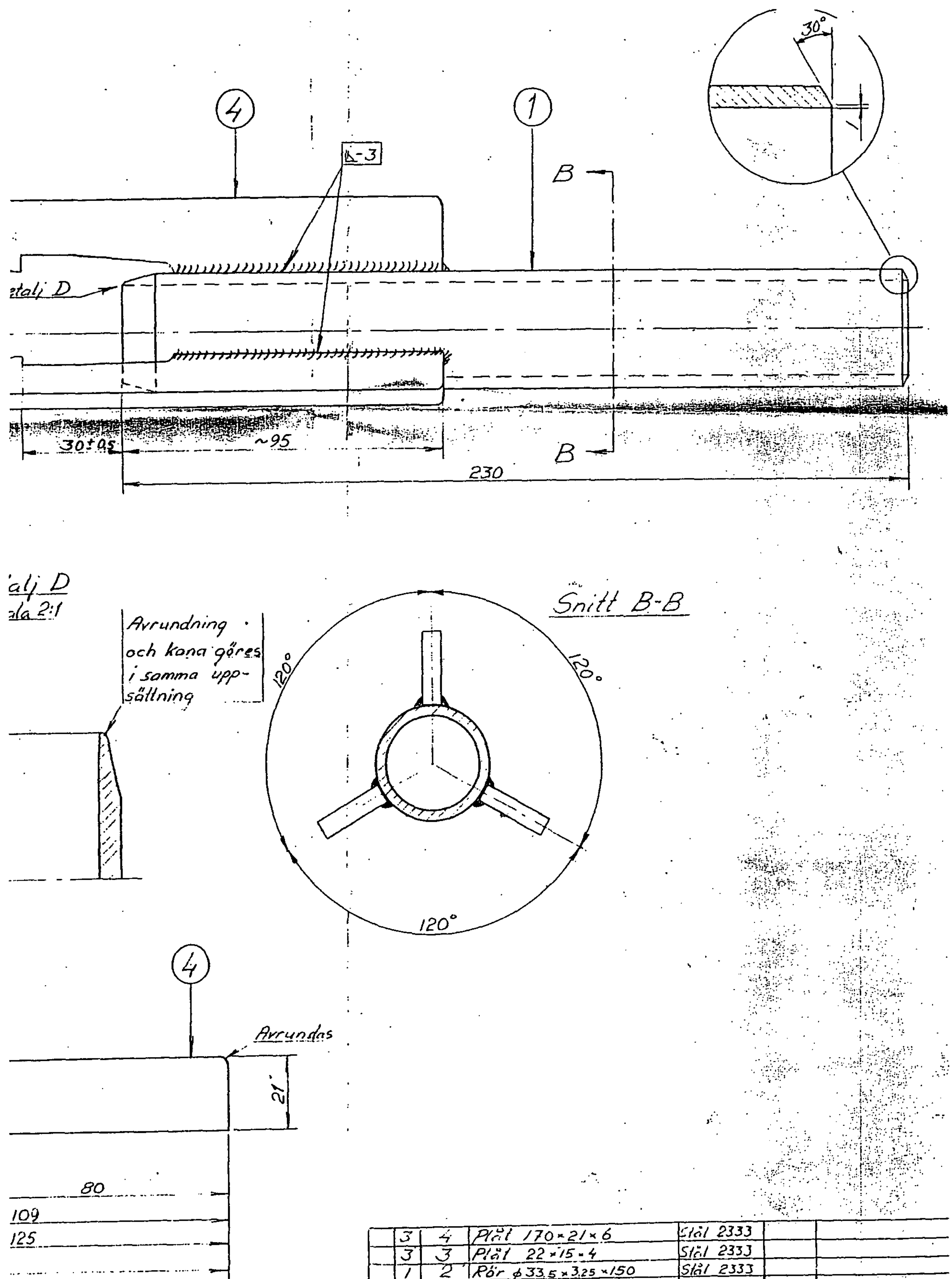
SVENSKA SKIFFEROLJE AB	Fastställd	Datum 19-5-60	Upplaga	Ersätter / Ersättes av	3 St

Type I, 2 b



Type II, 2 b differs from type I, 2 b by 2 m (6'7") of 18/8 stainless steel burner casing, 89 x 3.25 mm (3.50" x 0.13"), placed at 7,7 – 9,7 m (25'3" – 31'10") in B 9 and at 6,7 – 8,7 m (22'0" – 28'7") in B 14 from bottom of casing.

SVENSKA SKIFFEROLJE AB	Fastställd	Datum	Upplaga	Ersätter / Ersättes av	
		20.5.60			3 St



B Antal	A Antal	Detalj nr	Benämning	Beteckning Dimension	Material	Vikt	Anmärkning
	3	4	Plåt	170×21×6	Stål 2333		
	3	3	Plåt	22×15×4	Stål 2333		
	1	2	Rör	ϕ33,5×3,25×150	Stål 2333		
	1	1	Rör	ϕ33,5×3,25×230	Stål 2333		

Konstr.	Ritad	Kontr.	Godkänd	Stand.	Datum	Skala	Ersätter	Ersatt av
	Klö		/4		28.1.60	1:1, 2:1		

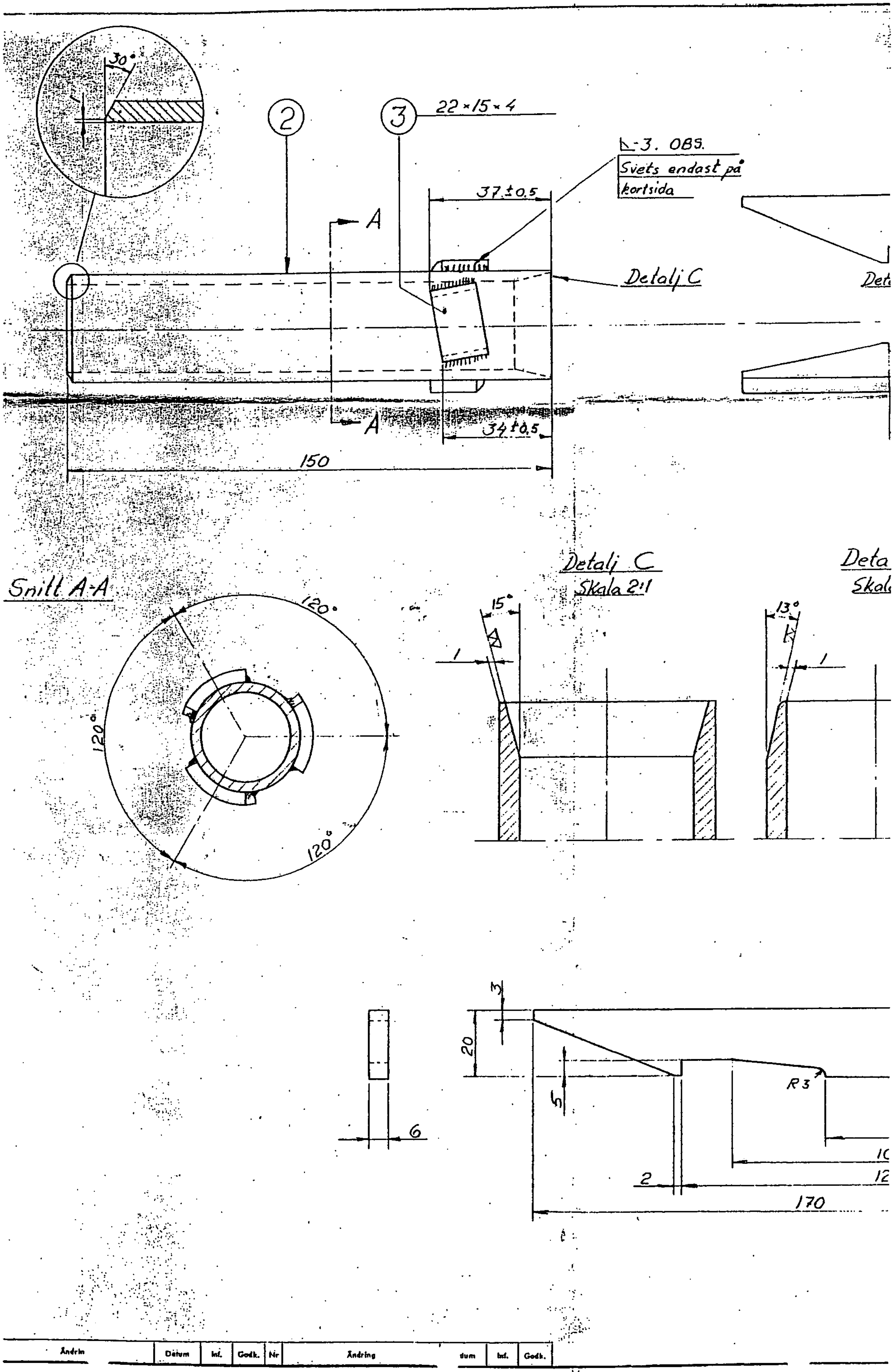
KVARN TORP
SVENSKA SKIFFEROLJE AB

KL Gasbrännarförsök

Brännar koppling

2-J-3513

159-3

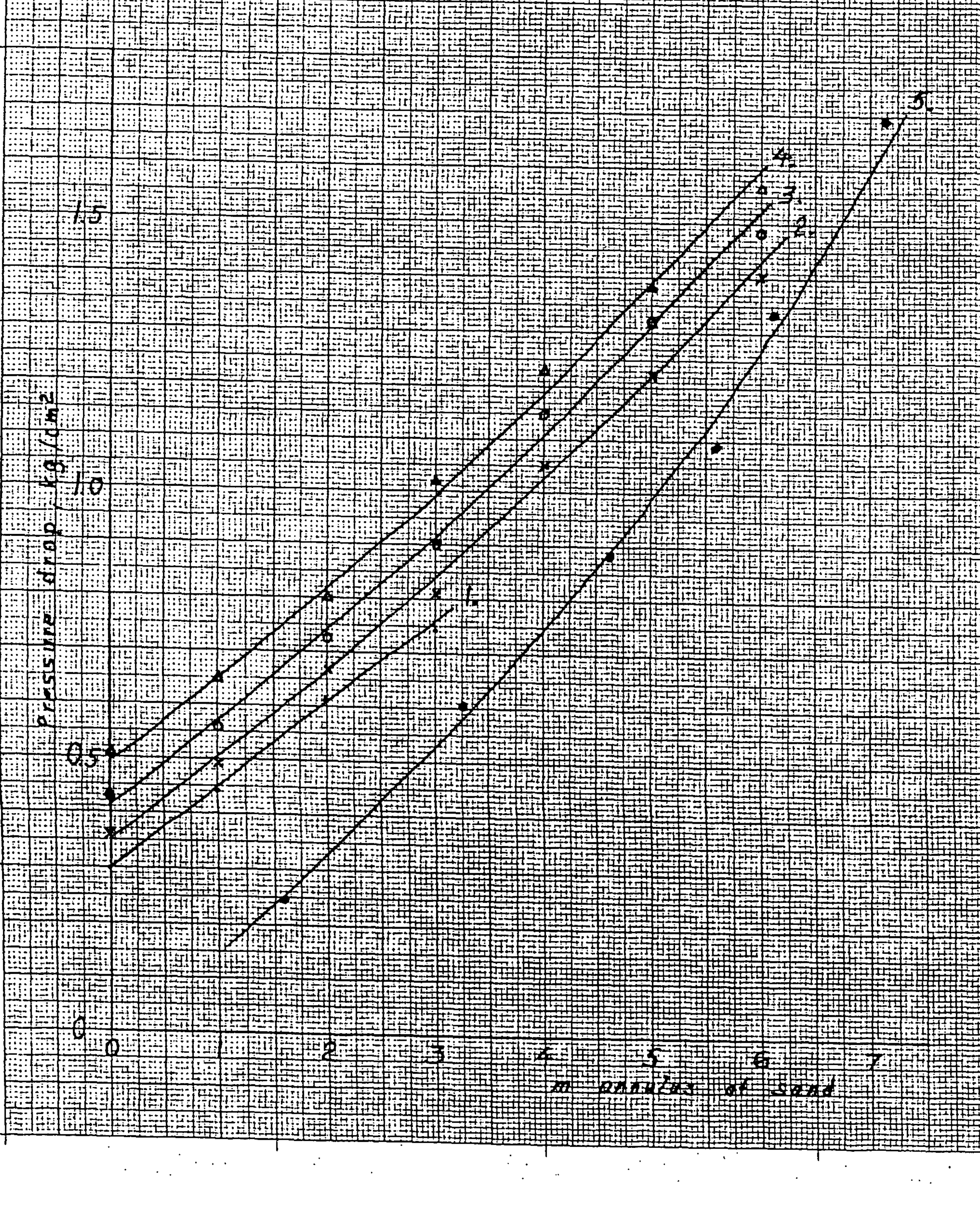


30°
2
3
22×15×4
-3. OBS.
Svets endast på kortsida
37±0,5
A
Detalj C
34±0,5
150
Snitt A-A
120°
120°
120°
Detalj C
Skala 2:1
15°
1
13°
1
3
20
5
6
R3
2
170
Ändrin
Datum
Inf.
Godk.
Nr
Ändring
Inf.
Godk.

sand height at fluidization
of sand with air.

March 28, 1960

Curve	Nm^3/h	SFt^3/h	$kg/m^2 sec$	$lb/ft^2 sec$	Corresp. to net Mcal/h	
1	14.5	511	1.17	0.240	11	Gas - KL 2; D_c = 3.24", D_B = 1.32"
2	15.8	558	1.28	.262	12	
3	17.1	604	1.38	.284	13	
4	18.4	650	1.49	.306	14	
5	11.3	400	1.21	.248	9	Well 120, Santa Cruz; D_c = 3.55", D_B = 1.66"
	19.8	700	2.11	.434	15	



Report on LINS Burner Test Gas-KL 2

April, 1960

Summary

Eight of the burner, those of type II, were started April 2nd without sand. The burner casings collected too much water and they had to be shut off at two times. After the first shut-down two of the burners were started with 1 and 2 m (3'3" and 6'7") sand resp. This worked better and at 75 hours the eight burners were restarted with 2 m sand and then filled up to 6 m (19'8") sand with 1 m each time at 26, 36, 48 and 123 hours from the last start. The other burners were then started at different times but with 3 m (9'10") sand and filled to 6 m sand within 30 to 43 hours.

All the burners were off between 414 and 580 hours because of power failures and difficulties with the gas-air mixture. The burners could not be started against the sand, therefore the sand was blown out and restarted with new sand. The amount of sand was increased from 3 (9'10") to 6 m (19'8") within 24 hours.

The net heat input was 14 Mcal per burner hour (56,000 BTU/b-h) except between 224 and 605 hours from the first start when 12.5 Mcal per burner hour (50,000 BTU/b-h) was used.

B 4, 5, 6, 9, 10 and 14 burner casings burned off. The adjacing temperature wells were then converted to electrical heaters.

B 4 casing burned off at about 2 m (7') above the bottom because the burner tube was in contact with the casing here caused by a crooked drill hole and thus a bent burner casing.

B 5 and B 6 burners showed no damage. The casings were probably burned off at the cone level, very likely because of weak welding seams.

B 9 burner could not be pulled. The burner casing and the T 9 B temperature casing burned off at 672 hours, thus 92 hours after the last long shut-down. It was found that the thermocouple could not be moved in T 9 B, when it was

going to be used at 29 hours after the last restart. The casing was probably weakened by thermal contraction during the shut-down.

B 10 failure was due to a supply tube burned off at the centralizers 0.2 m (8") above the cone.

In B 14 only the supply tube could be pulled. Even the T 14 B casing burned off. During the operation and after the shut-downs the following listed difficulties occurred, viz.

A. Burner had to be pulled because of sand plug in burner tube during operation.

B. Burner had to be pulled because of sand plug in burner tube after a shut-down.

C. Burner had to be pulled because the burner tube coupling could not be unlocked after a shut-down.

D. Sand plug in burner tube had to be removed with air. (Burner shut off.)

E. Water in burner casing had to be removed with air. (Burner not shut off.)

F. Unknown reasons

The number of each type of disturbance was:

Burner	A	B	C	D	E	F
B 2		1				
B 3		1				
B 4						
B 5						
B 6		1		1		
B 7	2			3	1	
B 8	2	1		1		
B 9	1		2	1	7	2
B 10						
B 11	1		1			1
B 12	1				4	
B 13	2		1	3	3	2
B 14				1	2	6
B 15	1			1	1	1
	10	4	4	11	18	12

The following table shows the amount of hours the burners were off and the total supplied net heat input until April 30th at 708 hours from the start.

Burner No.	On, hours	Off, hours Shut-downs	Off, hours A, D, F events	Heat input 10^3 Mcal	Heat input 10^6 BTU	Remarks
B 2	319	171	0	4.15	16.5	
B 3	382	171	0	5.00	19.8	
B 4	33	0	0	0.53	2.1	Cas. burned off.
B 5	92	0	0	1.26	5.0	" " "
B 6	209	177	3	2.63	10.4	" " "
B 7	343	348	18	4.50	17.9	
B 8	483	219	6	6.52	25.9	
B 9	435	224	13	5.71	22.7	" " "
B 10	174	48	0	2.37	9.4	" " "
B 11	128	330	8	1.74	6.9	
B 12	187	519	2	2.46	9.8	
B 13	375	327	6	4.98	19.8	
B 14	298	55	8	3.90	17.5	" " "
B 15	187	518	3	2.51	10.0	
Average per burn.	260			3.44	13.7	

Thus only eight burners remained. At the end of the month B 13 was shut off but will soon be restarted. The other burners were working all right, and the top of the fluidized sand bed was about 13 m (43′) above the bottom of the burner tube or 3 to 5 m (10′ to 16′) above the cone.

Operation

The description of the operation has been divided into three periods according to the main changes and shut-downs during April. A summary of the test data is made on Tables 1 through 6. The complete test data for each burner are not included in the report but they will be available later. The heat distribution in the temperature wells T 4 B, T 9 B and T 14 B is shown on Fig. 1. Figs. 2 through 9 give the temperature curves for the other temperature wells. The heat input is always the net heat input.

Until 75 hours from start

The burners of type II were first started, thus those with 2 m (6'7") of 18/8 stainless steel in the burner casing at the cone level, because these should resist higher temperatures than the other burners and therefore could be heated under more severe conditions during the first time of testing. Primarily, a good starting method had to be found out.

B 7, 8, 9, 10, 12, 13, 14, 15 were started April 2nd without sand and with the intention of adding sand when the first condensed combustion water had boiled out from the lower part of the burner casing. The burners were started with a heat input of 10 Mcal per burner-hour (40,000 BTU/b-h). The start met with difficulties and the burners went out, when the heat input was raised. This was found to be due to a too rich gas-air mixture, caused by a fault in the mixing equipment.

After adjustment the burners were easily restarted and the heat input was easily increased to 14 Mcal per burner-hour (56,000 BTU/b-h).

It was now assumed that the water condensation in the bottom part of the casing could be prevented by adding some sand to the burner immediately after the start. The sand would fluidize and thus obtain radiation heat from the burner tube besides the convection heat from the flue gases going through. Therefore, more heat should be distributed to the bottom of the casing with sand than without sand already at the start of the burner. Some water condensation would anyway occur in the beginning and, if too much sand was used, this could result in too wet sand and clogging of the burner tubes. The rate of heat input is also important. As already mentioned at least 14 Mcal per burner-hour (56,000 BTU/b-h) can be used instead of 10 Mcal per burner-hour (40,000 BTU/b-h). Therefore, new attempts to light the burners without sand but with a higher heat input were made. The intention was also to find out, if the large amounts of water already collected in the burner could be boiled out at the higher heat input.

The burners were lit at 32 hours and the heat input was adjusted to 14 Mcal per burner-hour. After a few minutes 1 m (3'3") S 9 sand was added to B 7 and 2 m (6'7") S 9 sand to B 8. The casings also contained about 0.5 - 1 m (2' - 3') water. This was also the case with B 9, 10, 12, 14 but no sand

was added to these burners. B 13, 15 still contained about 4 - 5 m (13' - 16') water. A new attempt with a sock tube around the bottom of the burner tube was also made in B 9.

A weak rupture disc burst after only 15 minutes so th burners went out and were not back in operation until after 35 hours. B 13 was not restarted because it had already accumulated more than 7 m (23') water, thus above the burner tube coupling.

B 9, 10, 12, 14 went out after 44 hours and B 7, 8, 15 were then shut off. The burners went out because ice was formed in the orifice plates, when the outside temperature was below + 2° C (36° F). Thus, the gas supply to the burners was choked. This must also have been the cause to the shut-down at 20 hours.

B 15 still contained about 4 m water, but it had started to boil out. This was indicated by the increase in the exhaust gas temperature. The other burners had collected about 1 - 3 m water, the smallest amount in B 8 with 2 m sand. This was promising, and it was decided to restart the burners with 2 m sand. The trial with the sock tube in B 9 was unsuccessful mainly because of too much water in the casing at the start. The burners were first pulled in order to blow and bail out all the water and the sand. A total heat input of 2,450 Mcal ($9.7 \cdot 10^6$ BTU) had been supplied to the burners.

At first the bottom part of the burner tube was sunk down hanging in a wire, part of which was fairly thin. When the burner tube was down on the bottom of the burner casing, the thin wire was easily broken by a short, fast pull, whereafter the other wire was brought up to the ground. Unfortunately in B 12 and B 15 the thin wire broke before the burner tube was down. The burner tube was dropped, and knocked out the bottom plate of the burner casing. However, the bottom of the burner casing was successfully tightened with cement. A rubber packer was first brought down to the bottom of the burner casing with 1/2" pipes, and then locked so it sealed the casing. After the 1/2" pipes were pulled the formation water (about 6 m) could be bailed out. Thereafter, cement was pressed down with air and was let to "burn" with 5 kg/cm^2 (70 psi) air pressure on for a few hours. After 2 - 3 days the cementing was repeated so about 1 m (3') of the casing was cemented. In order not to heat this part of the casing, which could result in the braking of the cement, about 1 m

sand was placed on the top of the cement and above the sand a 150 mm (6") long piece of 2 1/2" pipe with bottom and top plates which would act as the new bottom of the burner casing. Thus, 2 m (6'7") of the casing was lost for heat supply to the shale. The burner tube was then shortened 2 m from 10 to 8 m (32'10" to 26'3") with the burner tube coupling placed 2 m below the cone, so the cone still would be within the place of the stainless steel part of the burner casing.

75 - 224 hours from start

B 7, 8, 9, 10, 13, 14 were restarted with a heat input of 14 Mcal per burner-hour (56,000 BTU/b-h) on April 5th at 75 hours. After half an hour 1 m S 9 sand was added and after another 30 minutes the amount of sand was increased to 2 m (6'7"). The pressure drop through the burners increased steadily from about 0.85 kg/cm^2 (12psi) to about 1.00 - 1.10 kg/cm^2 (14 - 15.5 psi) due to the condensation of about 2 m water in the burner casings. However, simultaneously the temperature of the exhaust gas increased to above the normal dew point of 60°C (140°F) which showed that the first condensed water began to leave the burner. At 101 hours, 26 hours after the restart, the pressure dropp and temperature of the exhaust gas had decreased so the burners contained less than 1 m of water. Therefore, another 1 m of S 9 sand was now added. The amounts of sand was then increased to 4 m (13'2") at 111 hours and to 5 m (16'5") at 123 hours. S 9 sand was used except for the 5th meter in B 8, 9, 10 where P sand was used.

The sand to B 14 was added later than the other burners, because the burner went out five times between 84 and 98 hours of unknown reasons. 3 m sand was added at 111 hours, 4 m sand at 123 hours and 5 m sand at 161 hours. The burner went off again at 133 and 141 hours. It was easily relit but the last time the sand was so wet so it clogged the burner tube. The sand plug was released by pressing through air of 5 kg/cm^2 (70 psi) pressure.

When the sand fluidized, the pressure drop varied rapidly, usually in a range of 0.05 - 0.10 kg/cm^2 (0.7 - 1.4 psi). The burner could also be pulled by hand. It was frequently checked by pulling it a few millimeters each time. The burner sank then down by itself. However, B 9, 10 and 14 did not do so, and they had been pulled altogether about 0.5 m (1'8"). It was tried to blow down B 14 with 5 kg/cm^2 (70 psi) air pressure, but even this pressure was insufficient to get the wet sand at the bottom to fluidize, so the burner

could get down by itself.

Taken sand samples showed that the sand fluidized only to the cone level and that the sand was wet. There was also water bubbling in some burners, in B 8 so much that the burner had to be shut off at 149 hours to pull the burner and blow out all the sand and water. It was restarted at 155 hours with 3 m sand and filled to 5 m sand at 162 hours. At 198 hours another meter of sand was added to the burners, P sand to B 10 and S 9 to the others. The sand now fluidized to 11 - 12 m (36' - 40') above the bottom of the burner casing, corresponding to a sand expansion of about 2. As some sand had clogged on the burner casing above the cone level and did not take part in the fluidization the true expansion was probably higher.

Because of the good results with the started burners, B 4, B 5 were started at 154 hours, B 3 at 155 hours and B 2, B 6 at 218 hours. 3 m sand was added to the burners within half an hour after the start. The amount of sand was increased to 4 m after 20 hours, to 5 m after 28 hours for B 2, 6 and after 43 hours for B 3, 5 and finally to 6 m after 30 hours for B 2, 6 and after 55 hours for B 3, 5. All the burners seemed to work fine with a sand fluidization to about 12 m above the bottom of the burner tube and the shorter adding time for the sand in B 2, B 6 seemed to be adequate.

B 4 was an exemption. The temperature, measured in T 4 B with thermocouples, showed 110°C (230°F) at 22 and 32 m (72' and 105') below ground surface and 120°C (248°F) at 30 m (99'), because 6,500 Mcal (26 million BTU) had been supplied to the adjacing electrical heaters in Row 87. Already at 8 hours from the start the temperature was 380°C (717°F) at 30 m. Therefore, 1 m S 9 sand was added. The temperature decreased now to 360°C (681°F) at 10 hours. Then the temperature increased again, and at 21 hours it was 520°C (968°F) at 30 m. It was feared that the flame was in the bottom of the burner tube but checking it by unlocking the burner tube coupling and by temperature readings in T 4 B showed that the flame was in the cone. The heat distribution at this time is shown on Fig. 1. It is interesting to note that the lowest temperature of 100°C (212°F) was 3 m (10') below the cone and that the temperature at 30 m or 8 m (26') below the cone was 285°C (514°C) higher than at the cone. After another 11 hours (186 hours) the temperature at 30 m decreased to 450°C (842°F) but at 38 hours (192 hours) the burner casing burned off. The burner tube coupling could not be disconnected and the burner could only be pulled 2 m (6.5'). Thus, the

bottom of the burner tube was stopped at 30 m (99'), where probably the burner casing burned off. It was now found that the drill hole had not been drilled straight and that it had been difficult to get the burner tube by in the burner casing at this depth. Therefore, the casing was bent here and the burner tube had been in direct contact with it which caused the high temperature. Only the top joint of the supply tube could be recovered.

At 222 hours the B 10 burner casing failed. Only the supply tube was pulled and it was found that even this one had burned off at the centralizers 0.2 m (8") above the cone. The failure was probably due to a material defect of the supply tube. Anyway, it showed that the flame must have been here and it might have started from a small hole on the supply tube obtained at the welding of the centralizers. Before the failure the burner did not fluidize the sand above the cone and there was water bubbling in the casing.

Ice forming in the orifice plats was prevented by placing these at the top of the supply tube and protecting them with sacks during the nights so the warm exhaust gases warmed up the plates. However, at two times ice was formed in the orifice plates so two burners went out each time.

224 - 580 hours from start

Because of the last burner failure B 10, it was feared that the heat input was too high. Therefore, it was decreased to 12.5 Mcal per burner-hour (50,000 BTU/b-h) at 224 hours. However, two more casing failures in B 5 and B 14 occurred during this time.

B 5 burner casing burned off at 246 hours. The burner was easily pulled and it showed no damage or corrosion. The sand, pressure and temperature data had not showed any abnormal values. Therefore, no certain explanation can be given to the failure. It can only be assumed that a weak welding seam burst.

B 14 burner casing and T 14 B temperature casing burned off at 361 hours. The burner tube coupling could not be loosened and even the whole burner was stuck. Only the supply tube was pulled. No reason is known for this failure either. The heat distribution was determined at 175 and 240 hours and was fairly even as shown on Fig. 1. The last temperature reading was taken at 346 hours only at the cone level and was 440°C (824°F), thus not particular

high, even if it was higher than in T 9 B. The sand had fluidized very well, about 12 to 13 m (40' to 43') above the bottom of the burner tube, thus 4 to 5 m (13' to 16') above the cone. However, the casing was collecting water and the top sand bed was wet. Some water had been removed by blowing air through a 1" air hose, sunk down to about 20 - 21 m (66' - 69') from ground surface.

B 11 was started for the first time at 242 hours. The same sock tube as tested earlier in B 9 was again tried. 3 m B 9 sand was added within half an hour after the start. However, the burner had to be shut off after 7 hours (249 hours) because the sand was clogged on the screen between the sock tube and the burner tube. The burner was pulled, the sock tube removed and the sand blown out. It was not restarted until 581 hours, because when it was ready for restart, one of the compressors had to be repaired and the other compresser could deliver air only for 8 burner at 12.5 Mcal per burner-hours.

B 12 and B 15 with the cemented bottoms of the burner casings were restarted with the 8 m (26'3") long burner tubes at 287 and 290 hours resp. 3 m (10') B 9 sand was added immediately after the start and the 4th and 5th m (13' and 16') of sand at 296 and 300 hours resp. The sand fluidized well, but already at 304 hours water was bubbling in the casings, and at 320 hours the sand was so wet that it clogged the bottom of the burner tubes. They were shut off, and because the sand plugs could not be removed with air through the burners they were pulled and all the wet sand was then blown out with air. The sand was probably poured into the burner too soon after the start.

At 325, 409 and 414 hours the 3 to 8 burners in operation and at 336 hours 4 of the 8 burners went out due to power failures and distortions in the gas mixing equipment. After the shut downs at 325 and 336 hours the burners were relit against the sand, however, with some difficulties for B 6, 7, 13 at the last time. They had to be shut off again at 338 hours because the sand did not fluidize. The sand had clogged the burner tubes, and the sand plugs were pushed out with 5 kg/cm^2 air pressure. However, B 7 had to be shut off again at 400 hours. The sand plug of wet sand was now so hard so it was impossible to remove it with air. The burner had to be pulled and all the sand was then blowed out. At the reinstalling of the burner the bottom part of the burner tube was dropped and knocked out the bottom plate of the

burner casing. Therefore, the casing had to be sealed with cement in the same way as was earlier done with B 12 and B 15. There had been difficulties before with B 7. Thus all the sand had to be replaced at 251 hours, because there was too much water in the casing. It was restarted at 266 hours with 3 m S 9 sand and filled up to 4.5 and 6 m S 9 sand at 271, 274 and 286 hours resp. After 409 hours only B 2, 3, 8 could be restarted while the burner tube couplings in B 9, 13 could not be unlocked and the sand plugged the burner tube in B 6 so hard that it could not be removed with air pressure of 5 kg/cm^2. After the last shut-down not even B 2, 3, 8 could be started against the sand. It clogged the burner tube too hard. The sand plugs were released with air but the sand clogged the burner tubes as soon as the air was removed. Therefore, it was decided to pull all the burners and blow out all the sand. Unfortunately, they could not be started until after 580 hours because enough sand was not available and the new sand delivery had been delayed.

This long shut-down was very disgusting because the burners, with the mentioned exemptions, had been running well and the sand was fluidizing about 2 - 3 m (7' - 10') above the cone. The heat distribution measured in T 9 B was excellent as shown on Fig. 1.

The supplied heat to the burners was increased from 17,100 Mcal ($68 \cdot 10^6$ BTU) at 224 hours to 35,700 Mcal ($142 \cdot 10^6$ BTU) at 414 hours.

580 - 708 hours

B 2, 3, 6, 8, 9, 11, 12, 13, 15 were started between 580 and 581 hours. 3 m S 9 sand was added immediately afterwards. The amount of sand was then increased to 6 m with one meter each time at 589, 593 and 604 hours except for B 13. At these fillings different amounts of a screened packing sand, called PS sand was used in B 6, B 9, B 11, B 12 and B 15 in order to investigate, if a smaller sand size would boost the fluidization.

The sieve analysis of the PS sand was:

>10	Mesh or	>2	mm =	0.1 %
10 - 18	" "	1 - 2	" =	32.4 %
18 - 35	" "	0.5 - 1	" =	53.7 %
>35	" "	>0.5	" =	13.8 %

The average particle size was 0.93 mm (0.037"), compared to 1.08 mm (0.043") and 1.40 mm (0.055") for the P sand and S 9 sand, resp.

The results of these tests cannot be obtained until next month.

B 13 did not receive its 4th m of sand until 606 hours because water had been bubbling in the burner and at several times clogged the sand and plugged the burner tube. 1 hour later the burner tube became completely plugged so the burner had to be pulled and all the sand was blown out. It was restarted at 676 hours with 3 m new S 9 sand. It was now tried to avoid the accumulation of the water in the bottom of the casing by adding the 4th and 5th m already at 680 and 681 hours in order to absorb the radiation heat to the sand from the upper part of the burner tube and the cone. However, it did not help and the burner had to be shut off again at 686 hours.

Water was also bubbling in B 7, 9, 12 at several times. The water was collected above the fluidized sand bed and was easily blown out with air through a 1" rubber hose sunk down to 15 - 20 m from ground surface.

The heat input was increased from 12.5 to 14 Mcal per burner-hour (50,000 to 56,000 BTU/b-h) at 605 hours. The sand now began to fluidize better and the top of the sand bed was expanded from about 10 - 11 m to about 13 m, counted from the bottom of the burner tube. The actual sand expansion cannot be given because undetermined amounts of sand had been lost through the exhaust gases.

B 6 and B 9 burner casings were burned off at [illegible] and [illegible] hours resp. The failures were probably due to weak weld seams on the casings because the burners worked all right with satisfactory sand expansion. The pulled B 6 burner showed no damage. B 9 burner could not be pulled. At about 600 hours, thus 20 hours after the last restart, it was found that the thermocouple could not be moved in T 14 B temperature casing. There must have been some bending of it, probably caused by thermal stress and shale expansion on the casing during the long shut-down between 414 and 580 hours. There had also been lots of trouble with water bubbling in the burner casing. Despite water was blown up several times with air, the sand never became dry even if it was fluidizing all right.

B 7 with a cemented bottom of the burner casing and with a burner tube

shortened to 8 m was started at 694 hours. 3 m S 9 sand was added immediately and within 10 hours it had received 6 m S 9 sand.

At the end of April after 708 hours there were seven burners (B 2, 3, 7, 8, 11, 12, 15) in operation and one (B 13) shut off which soon will be restarted again. A total heat energy of 48, 300 Mcal ($192 \cdot 10^6$ BTU) had been supplied through the burners.

Närkes Kvarntorp, July 29, 1960

Bengt Persson

(Bengt Persson)

Time Date April	Hours from start	Burners amount	Heat input Acc. net 10^3 Mcal	Remarks
2	0	8	0	B 7, 8, 9, 10, 12, 13, 14, 15, those of type II started without sand. 10 Mcal/b-h. They were difficult to light. It took 2 h.
	1	0		Off when h.i. incr. to 11 Mcal/b-h.
	2	8		On. 10 Mcal/b-h.
	7	0		Off when h.i. incr. to 11 Mcal/b-h.
	8	8		On. 10 Mcal/b-h.
3	20	2		All burners except B 13 and 15 off. 3 - 4 m water collected in b-casings. H.i. incr. to 13 Mcal/b-h.
	24	0		B 13 and 15 off. Gas-air mixture out of control.
	35	7		B 7, 8, 9, 10, 12, 14, 15 on. They had been started at 32 hours but a rupture disc burst after 15 min. The water except 0.5 - 1.0 m had been removed but not in B 13, 15. 1 m sand added to B 7 and 2 m to B 8. B 13 could not get started 2nd time because the water was above b-tube coupl. Sock tubs installed in B 9. Leakage of Hg in gasmanometer was discovered and tightened. Therefore, too much gas had been used ealier. Heat input 14 Mcal/b-h.
4	39	7		B 9 off. On after a few minutes.
	41	7		B 14 off. On " " " "
	42	7		B 14 off. On " " " "

Time Date April	Hours from start	Burners amount	Heat input Acc. net 10^3 Mcal	Remarks
4	44	0	2.45	B 9, 10, 12, 14 went out when the gas supply was choked because ice was formed in the orifice plates at outside temp. lower than + 2°C. B 7, 8, 15 were shut off. B 15 still contained about 4 m water. The others had collected up to 3 m water, least in B 8 with 2 m sand.
5	75	6		B 7, 8, 9, 10, 13, 14 started with 14 Mcal/b-h. 1 m sand added after 1/2 hour and another m (= 2 m) added after 1 hour from start. The amount of sand was then continously increased to 6 m.
				The burners had been pulled, the water blown out, the orifice plates moved closer to the top of the b-casing and during nights covered with sacks to avoid ice-forming.
				B 12, 15 burners were dropped in b-casings so the bottom plates were knocked out.
	84			B 14 off. On after a few minutes.
6	90			B 14 off. On " " "
	91	5		B 14 off.
	93	6		B 14 on. B 9 off. On after a few minutes.
	94	5		B 14 off.
	97	6		B 14 on.
	98	5		B 14 off.

Time Date April	Hours from start	Burners amount	Heat input Acc. net 10^3 Mcal	Remarks
6	99	6		B 14 on.
7	133	5		B 9 off. Could not unlock b-tube coupl.
				B 14 off. On after a few minutes.
8	141	4		B 14 off. Sand plug in b-tube.
	143	5		B 14 on.
	145	6		B 9 on.
	149	4		B 14 shut off to blow burner down 0.5 m to bottom of b-casing. Could not start it then, because sand plug in b-tube was formed. Had to pull it up 0.5 m again.
				B 8 shut off. It had collected too much water. Sand and water had to be removed.
	152	5		B 14 on.
	154	7		B 4 and B 5 started with 3 m sand added in 1/2 hour, then increased to 6 m.
	155	9		B 3 and B 8 started also with 3 m sand.
9	168	9		B 13 off. On after a few minutes.
10	190	8		B 7, 13 off. Fuel gas choked by ice in orifice plates. B 7 on after a few minutes. Could not disconnect B 13 b-tube coupl.
	192	7		B 4 burner casing burned off.
	196	8		B 13 on.
	198	8		B 13 off. On after a few minutes.

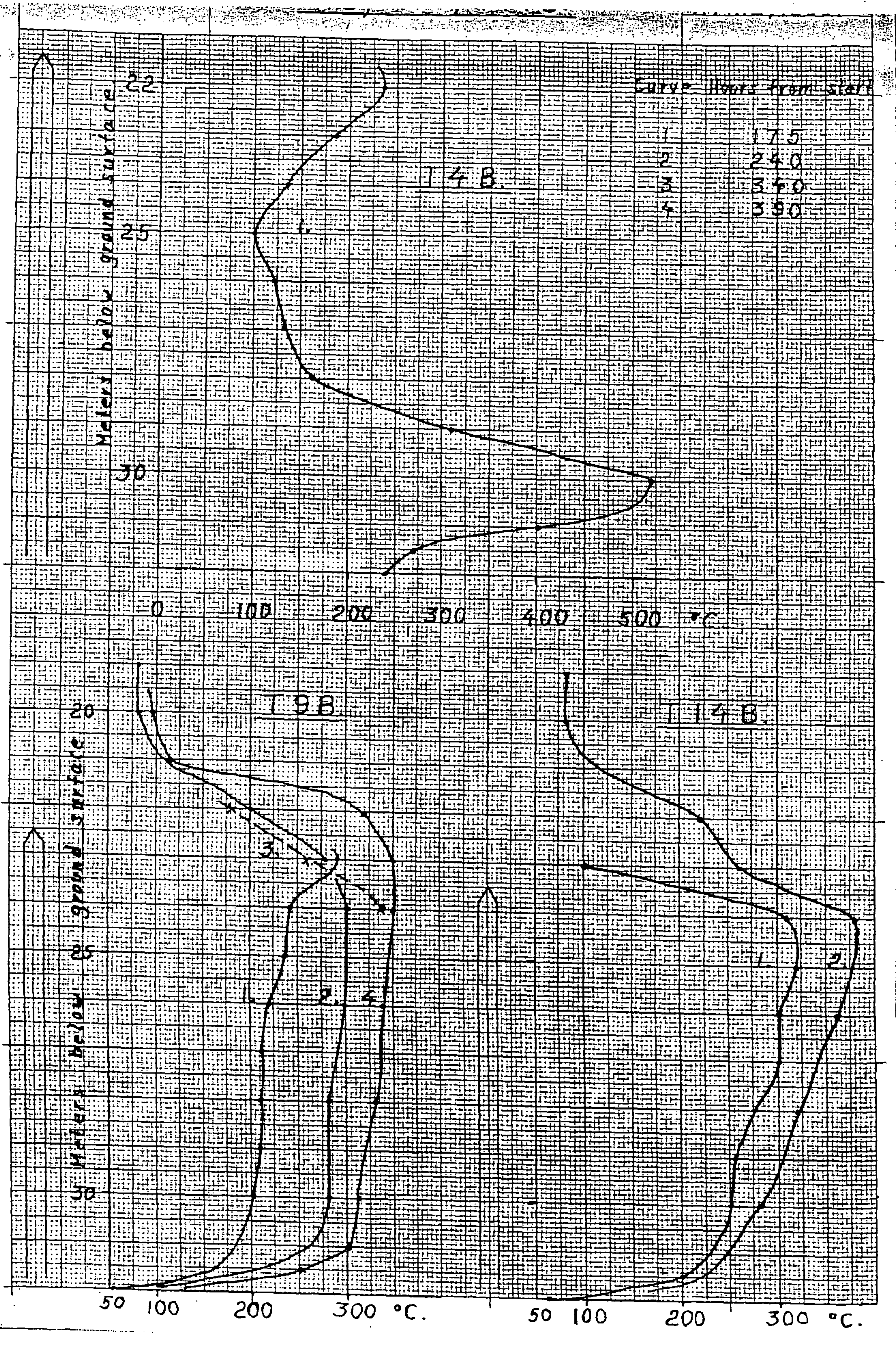
Gas-KL 2

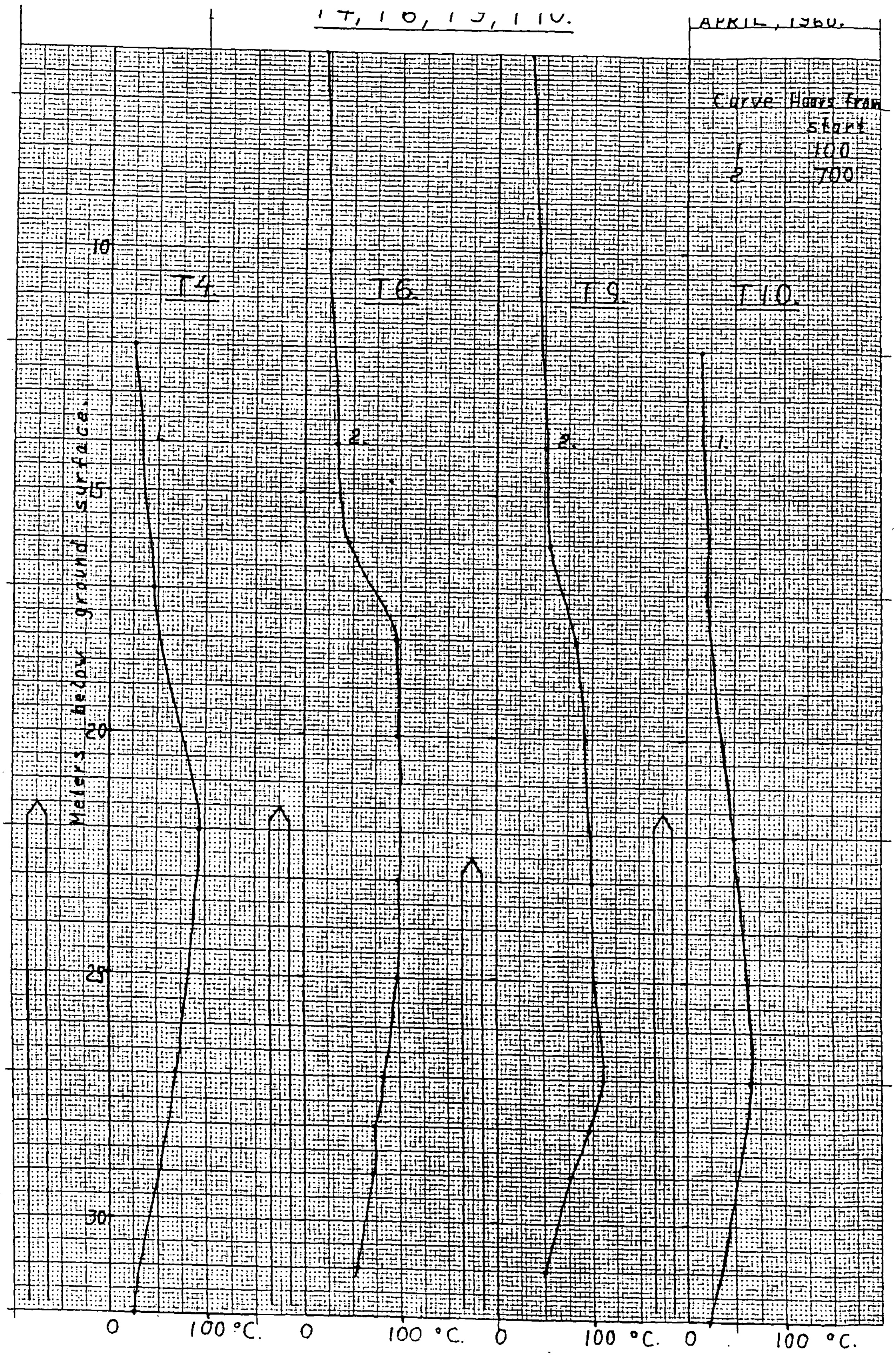
Time Date April	Hours from start	Burners amount	Heat input Acc. net 10^3 Mcal	Remarks
11	207	7		B 13 off.
	208	8		B 13 on.
	211	7		B 13 off. Ice in orifice plate.
	212	8		B 13 on.
	214	8		B 13, 14 off. Ice in orifice plates. On after a few minutes. B 14 on by itself when the orifice plate was warmed up.
	218	10		B 2, 6 started 3 m sand, then incr. to 6 m.
	222	9		B 10 burner casing and supply tubs burned off.
	224	9	17.06	Heat input decreased to 12.5 Mcal/b-h.
12	242	10		B 11 started. 3 m sand. Sock tube on b-tube.
	246	9		B 5 burner casing burned off.
	249	8		B 11 off. Sand plug in b-tube.
	251	7		B 7 off. " " " "
13	266	8		B 7 on.
14	287	9		B 12 on. 3 m sand, then incr. to 5 m.
	290	10		B 15 on. 3 m " " " " 5 m.
15	320	8		B 12, 15 off. Sand plug in b-tube.
	325	0		Fuse failure to one of the compressors. All burners off.
16	329	5		B 2, 3, 8, 9, 14 on.
	330	8		B 6, 7, 13 on.

Time Date April	Hours from start	Burners amount	Heat input Acc. not 10^3 Mcal	Remarks
16	336	4		B 6, 7, 9, 13 off. Gas-air mixture out of control.
	337	8		B 6, 7, 9, 13 on.
	338	5		B 6, 7, 13 shut off. No fluidization. Sand plug in b-tube removed with air.
	339	6		B 13 on.
	340	7		B 7 on.
	341	8		B 6 on.
17	361	7		B 14 burner casing burned off.
19	400	6		B 7 shut off. No fluidization.
	409	0		All burners off. Gas-air mixture out of control.
	410	3		B 2, 3, 8 on. Could not loosen b-tube couplings of B 9, 13. Too wet sand in B 6.
	414	0	35.70	B 2, 3, 8 off. Power off during 2 hours. Could not restart the burners against the sand. All burners had to be pulled to blow out the sand. No new sand available because of late delivery.
25	580	5		B 2, 3, 6, 8, 9 on. 12.5 Mcal/b-h.
	581	9		B 11, 12, 13, 15 on.
26	598	8		B 13 shut off. No fluidization. Blown with air.
	599	9		B 13 on.
	602	8		B 13 shut off. No fluidization. Blown with air.

Time Date April	Hours from start	Burners amount	Heat input Acc. net 10^3 Mcal	Remarks
26	603	9		B 13 on.
	605	9		14 Mcal/b-h.
	607	7		B 6 burner casing burned off. B 13 shut off. No fluidization. Could not restart B 7, B 13 because one compressor used too much oil and was shut off.
27	626	6		B 9 shut off. No fluidization. Blown with air.
	627	7		B 9 on.
29	670	5		B 11, 15 off. Unknown reason.
	671	6		B 15 on.
	672	5		B 9 burner casing and T 9 B casing burned off.
	676	7		B 11, 13 on.
30	686	6		B 13 shut off. Too much water in b-casing. All sand and water had to be blown out.
	694	7		B 7 on.
	708	7		48.26 Mcal (192 . 10^6 BTU) supplied through the burners.

FP/Emm
29.7. 1960.


Curve Hours from start
1 175
2 240
3 340
4 390
T4B.
Meters below ground surface
22
25
30
0 100 200 300 400 500 °C.
T9B.
T14B.
Meters below ground surface
20
25
30
1. 2. 3. 4.
50 100 200 300 °C.
50 100 200 300 °C.



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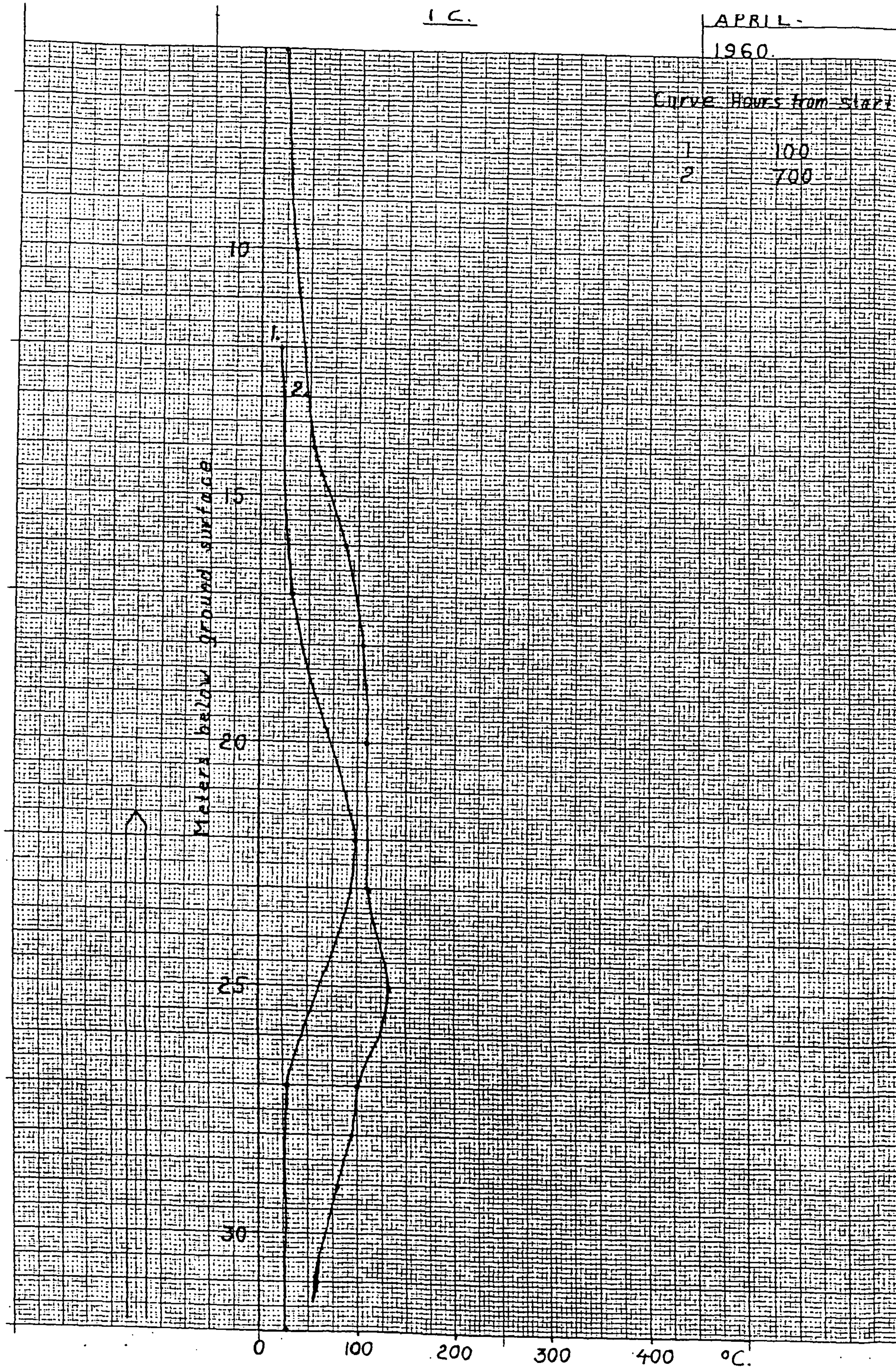
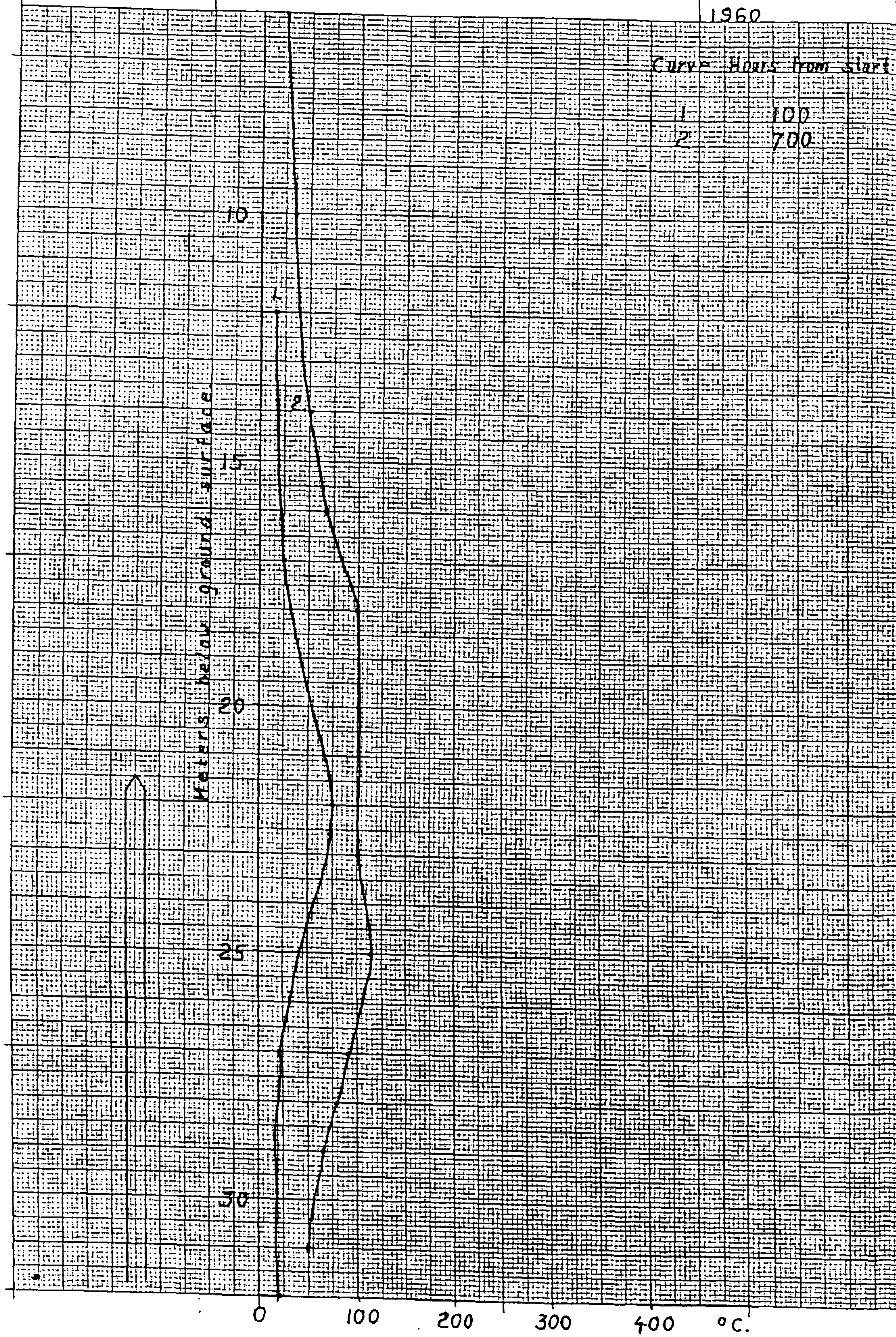
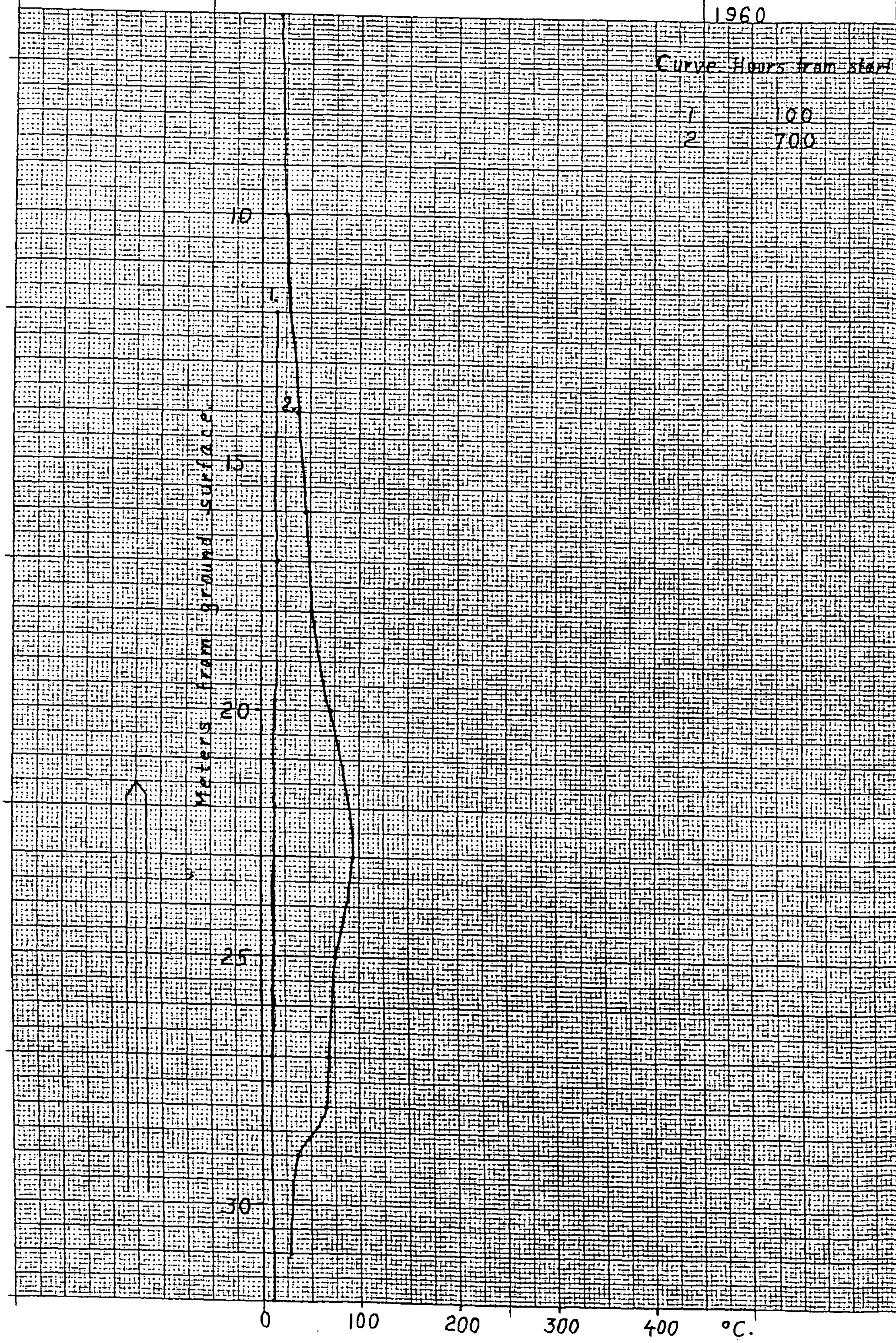

I C.
APRIL
1960
Curve Hours from start
1 100
2 700
1.
2.
Meters below ground surface
10
15
20
25
30
0
100
200
300
400
°C.

APRIL - 1960


Curve Hours from start
1 100
2 700
Meters below ground surface
10
15
20
25
30
1
2
0
100
200
300
400
°C.

1 /.

APRIL - 1960



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13501 - 523 A4 - 1 x 1 mm

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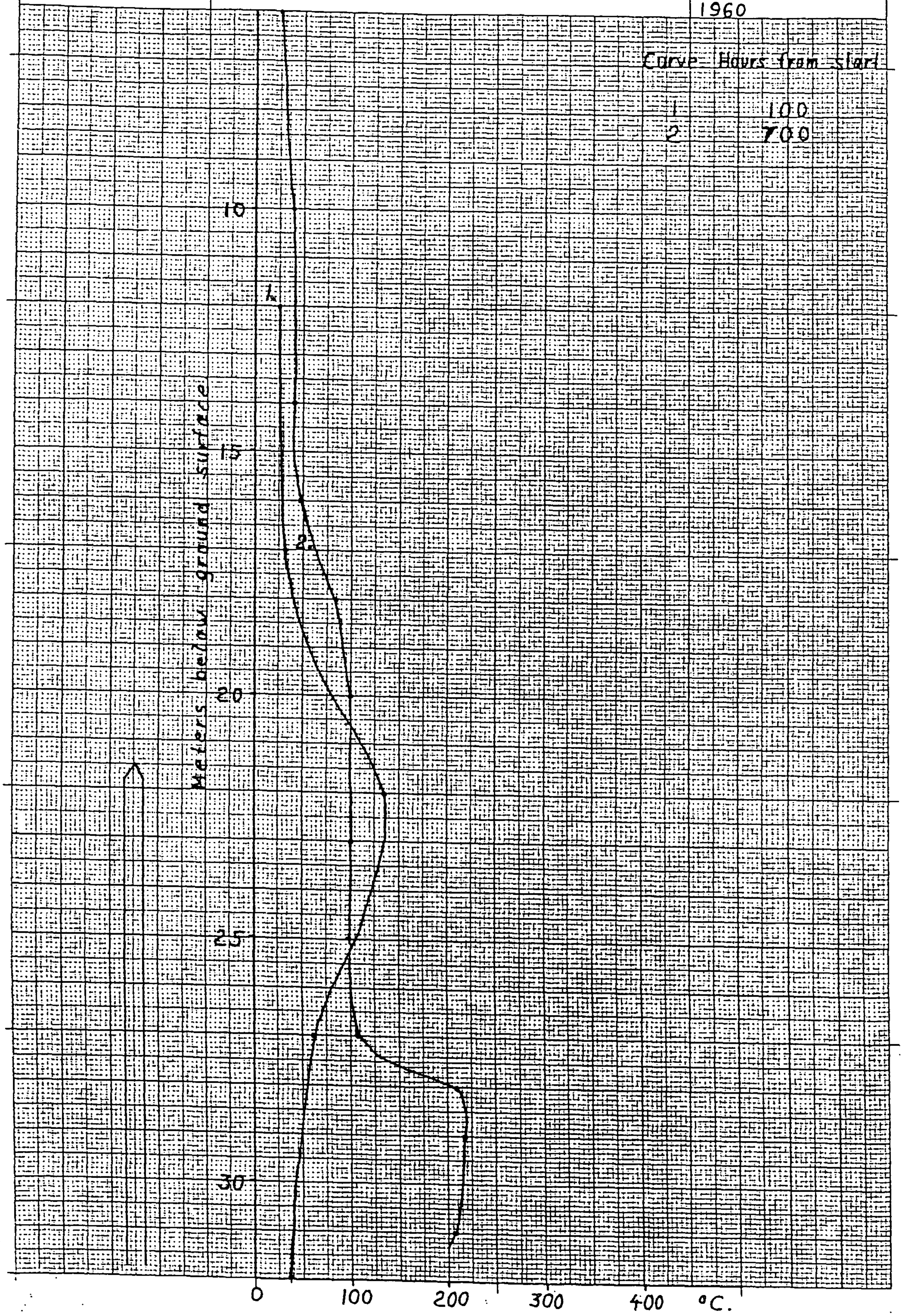

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T11.

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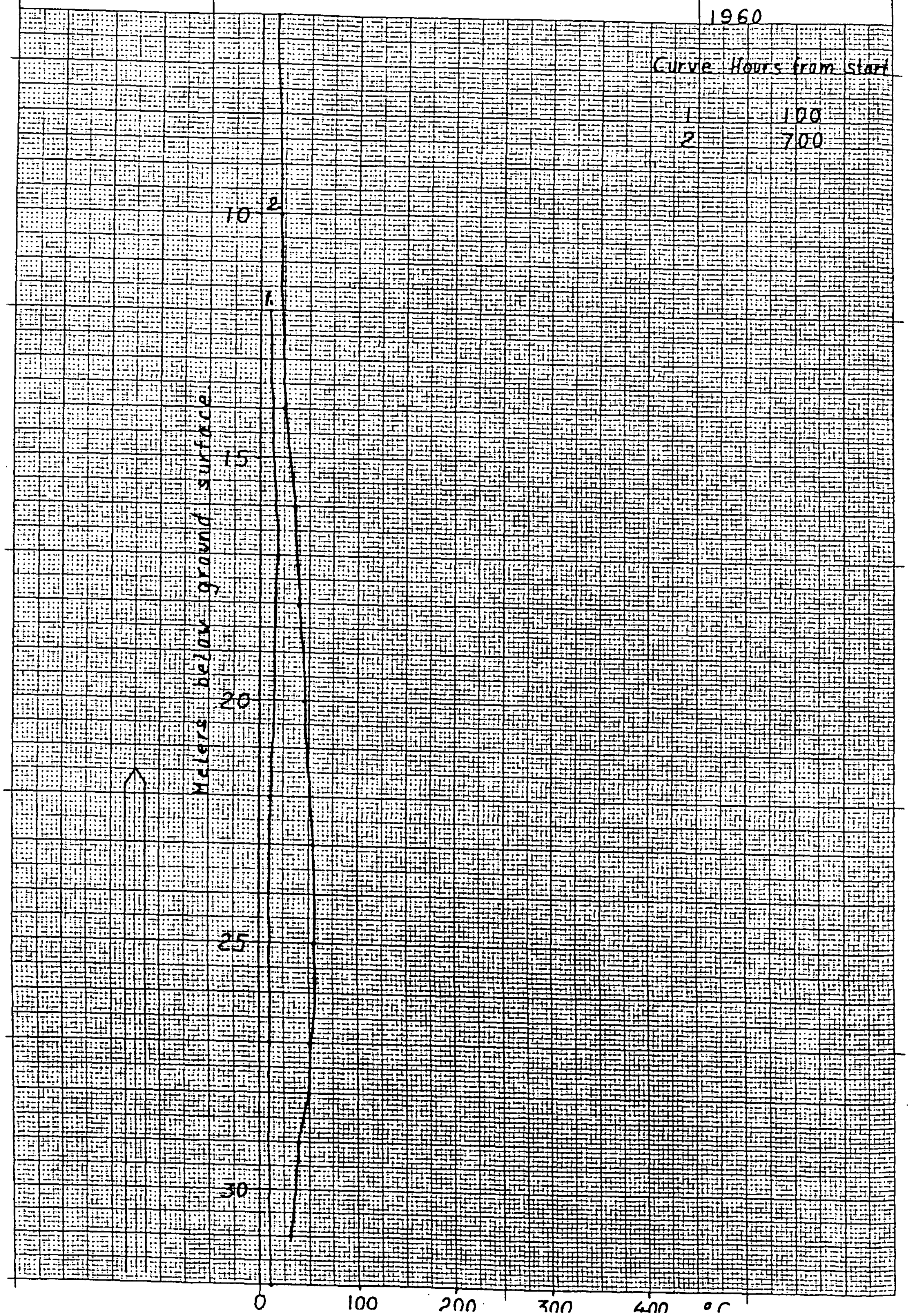

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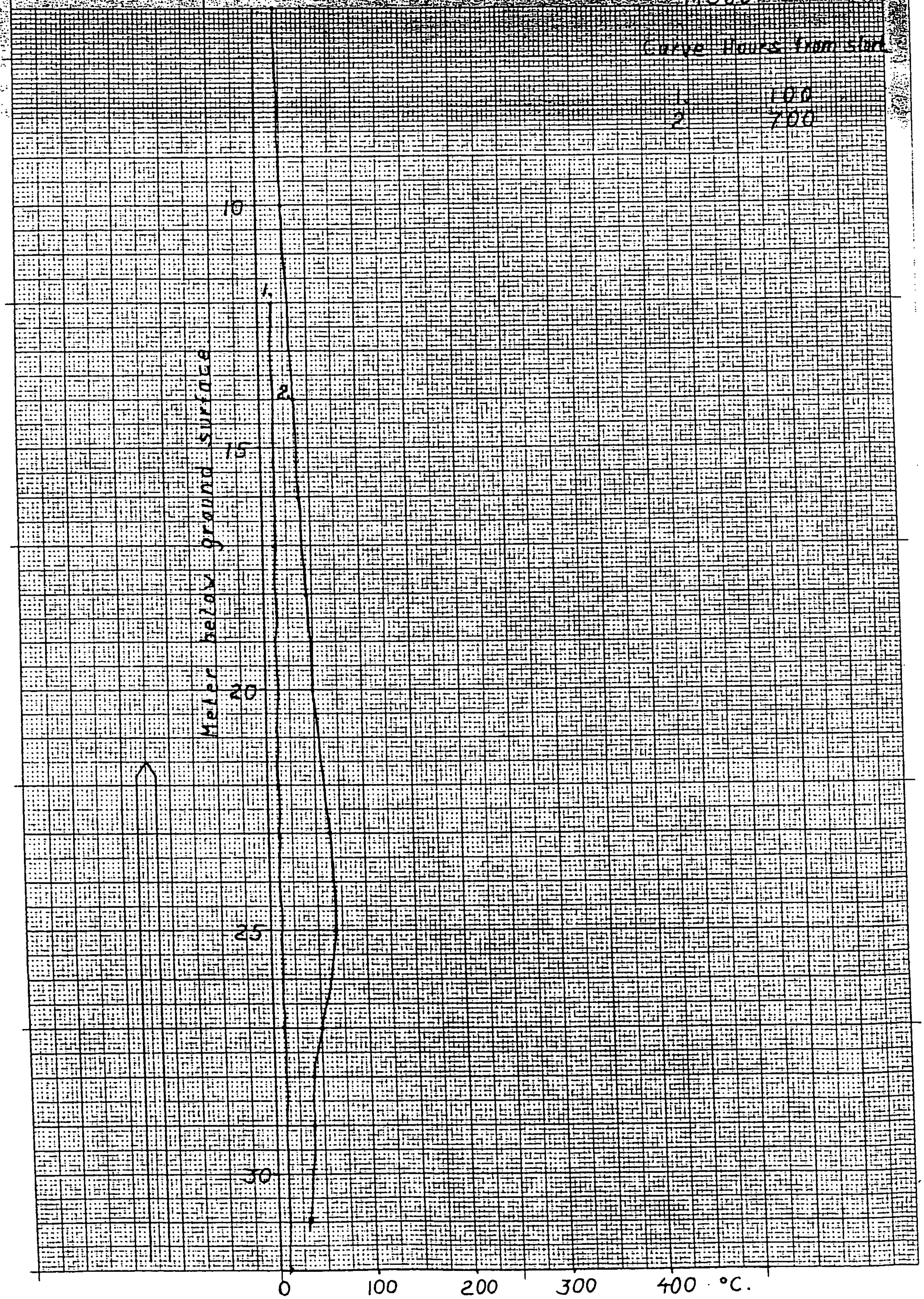
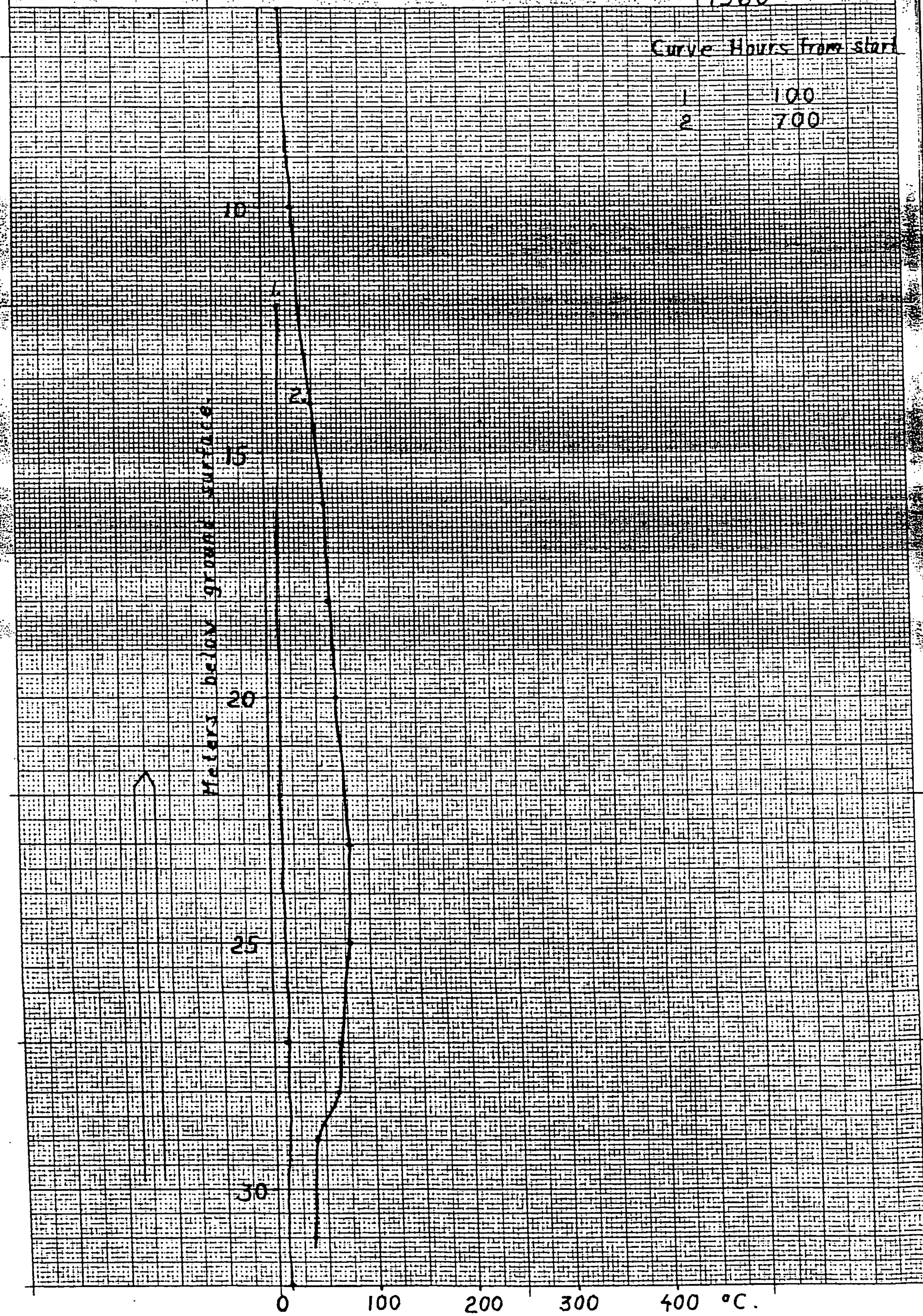

Curve Hours from start
1 100
2 700
1
2
10
15
20
25
30
Meter below ground surface
0
100
200
300
400 °C.

115.

APRIL –
1960



ESSELTE
4446

Gas-KL 2, B 2

Time: Date May	Time: Hours from start	Heat input total 10^3Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm²	Temp. Exhaust gas °C	Remarks
4	786		4.0	13.4	3.4	1.85-1.95		
	794		5.1					
	798	5.41						S 9 sand added.
	799							Off. Gas-air mixture out of control.
	800			14.3		1.85-2.00		On.
5	817	5.66						
	822			13.4		1.70-1.85		12.5 Mcal/b-h.
6	846		4.5	14.0	3.1		55	
			6.0					S 9 sand.
7	856			12.7	2.1	1.80-1.90	56	
	870			14.4		1.80-1.90	60	
8	894			13.6		1.70-1.85	58	
9	902	6.72						
	908			13.7		1.75-1.90	58	14 Mcal/b-h.
	910	6.84						Water blown up 2 times 12.5 Mcal/b-h.
10	942		4.0	13.6	3.4	1.65-1.80	58	
			6.0					
	952			14.2	2.4	1.80-1.95		S 9 sand.
11	960							Sand plug at 16 m removed.
	966							Sand plug at 17 m removed.
13	1013		4.8	13.0	2.7	1.75-1.90	58	
	1014	8.14						Off. Power failure.
	1016		6.0					On. S 9 sand.
	1028			15.1	2.5	1.90-2.05	58	
14	1051	8.57						Off. Air failure.
15	1063							On. Sand plug in b-tube removed with air before start.
16	1094		5.5	13.0	2.4	1.80-2.00	58	
			6.0					
17	1106			14.0	2.3	1.85-2.00	58	
18	1130			14.1		2.0 -2.1	58	Sand and water plug at 16 m removed.
	1137	9.50						Shut off for installing of 1.5 m coupling tube. Burner tube coupling had been leaking. Upper part badly erroded.
	1140		6.0					On. S 9 sand.

Time Date May	Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
19	1154			14.5	2.4	2.0 -2.15	58	
	1170	9.87						Off. Gas-air mixture out of control.
	1171							On.
20	1184		5.6	14.6	2.6	1.9 -2.0	56	
	1187	10.07						Shut off for cleaning of mixing equipment.
	1192		6.0					On.
21	1202			14.5	2.4	2.0 -2.15	58	
22	1245			15.0		2.05-2.1	57	Sand plug at 16 m removed.
23	1260		5.9 6.0	15.3	2.6	2.05-2.15	58	
24	1274			15.0	2.5	2.05-2.15	57	
25	1298			15.7		2.05-2.55	58	
26	1327							Water and sand plug at 12 m removed.
	1341							Water and sand plug at 12 m removed.
27	1346			14.5	2.9	2.0 -2.15	58	
	1350							Sand plug at 14 m removed.
	1354		5.1 6.0	14.7	2.5	2.05-2.15	58	
28	1370			14.7		2.0 -2.1	59	
	1371							Sand plug at 14 m removed.
29	1400			14.9		2.0 -2.15	59	Sand plug at 13 m removed.
30	1418			15.2		1.9 -2.0	67	
	1421						74	Smell of pyrolysis gases.
	1422	12.95						Burner shut off. Leakage of pyrolysis gases through burner casing. A rubber packer was pressed down to 14 m when it was stopped probably on a broken welding seam. The burner pipes were undamaged. There was some corrosion on the coupling tube and there had been a little leakage through the burner tube coupling.

Gas KL 2, B 3

Time Date April	Time Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	Sand Fluidiz. B m	Sand Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
8	155	0	3					Start. 14 Mcal/b-h. S 9 sand.
9	162					1.01-1.03	65	
	172					1.15-1.20	58	
	174		4			1.38-1.45	61	1 m S 9 sand added.
10	196			11.3		1.40-1.45	60	
	198		5					1 m S 9 sand added.
11	210		6					1 m S 9 sand added.
	222			12.8		1.80-1.90	61	
	224	0.97						12.5 Mcal/b-h.
12	250			11.0		1.80-1.82	63	
	252							0.5 m S 9 sand added.
13	272			12.0		1.80-1.90	61	
14	296			12.5			59	
15	320			11.1		1.72-1.80		
	325	2.23						Off. Compr. stopped.
16	329							On.
	334			11.0		1.60-1.70		
	346			11.5		1.65-1.70		
18	385			11.6		1.73-1.80	58	
19	402			12.1		1.78-1.82		
	409	3.23						Off. Gas-air mixture out of control.
	410							On.
	414	3.28						Off. Power off. Could not start against the sand. All sand had to be blown out.
25	580		3					On. S 9 sand.
	584					1.0	56	
26	589		4					1 m S 9 sand added.
	593		5					1 m S 9 sand added.
	600			11.0		1.47-1.52	56	
	604		6					1 m S 9 sand added.
	605	3.59						14 Mcal/b-h.
	609			11.6		1.70-1.80	59	
28	642			13.5		1.80-1.90		Wet sand.
	654			12.7		1.83-1.95	58	Dry sand.
29	668			13.4		1.78-1.85		
30	708	5.00		12.7		1.60-1.75		During April: On 382 hours, off 171 hours.

Gas-KL 2, B 3

Time Date May	Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
2	748			12.2		1.65-1.75		14 Mcal/b-h.
	749							0.6 m S 9 sand added.
	758			13.7		1.80-1.90		Sand plug in burner casing blown out.
4	786		3.7	13.7	3.7	1.85-1.97		Water in burner casing blown out.
	794		4.8					S 9 sand added.
	798	6.26						Off. Gas-air mixture out of control.
	799							On.
	800			15.5		1.90-2.00		
5	817	6.51						12.5 Mcal/b-h. Water blown up.
	822			13.8		1.70-1.80		
6	846		4.3	13.5	3.1	1.80-1.90	57	
			6.0					
	850							S 9 sand Water blown up.
7	856			13.5	2.3	1.75-1.90	58	
	870			13.9		1.75-1.90	68	
8	894			14.3		1.70-1.80	66	
9	902	7.57						Burner casing burned off. Could only pull supply tube. A rubber packer was stopped at 8 m, probably at a weld, which might have burst. Thus, only a weld failure. During May the burner was on 193 hours and off 1 hour. Totally it had been on 575 hours and off 172 hours.

Gas-KL 2, B 4

Time: Date April	Time: Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
8								Temp. in T 4 B: 110° C at 22 m; 120° C at 30 m; 110° C at 32 m
	154	0	3					Start. 14 Mcal/b-h. S 9 sand.
9	160					1.01-1.03		
	162					1.01-1.08	60	380° C at 30 m.
	163		4					1 m S 9 sand added.
	164					1.30-1.35	58	360° C at 30 m.
	175					1.37-1.42	61	520° C at 30 m. See temp. diagram, Fig. 1.
	186							450° C at 30 m.
10	192	0.53						Off. Burner casing burned off at 30 m. When trying to pull the burner, it was stuck at 30 m. Could not unlock burner tube coupling. The burner tube was probably in contact with the burner casing at 30 m, because this was bent here. It was later learned that the drill hole had not been drilled straight and that it had been difficult to get the burner tube by at 30 m at the installing.
12	240							T 4 converted to electrical heater 88/88.

Gas-KL 2, B 5

Time Date April	Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
8	154	0	3					Start. 14 Mcal/b-h. S 9 sand.
9	162					1.00-1.08	61	
	174		4			1.33-1.41	61	1 m S 9 sand add d.
10	196			10.3		1.35-1.40	61	
	198		5			1.57-1.60		1 m S 9 sand added.
11	210		6					1 m S 9 sand added.
	222			12.3		1.70-1.80	58	
	224	0.98						12.5 Mcal/b-h.
12	244			10.5		1.65-1.70	60	
	246	1.26						Off. Burner casing burned off. Burner easily pulled. It showed no damagae or corrosion. Burner had been on 92 hours.

Gas-KL 2, B 6

Time: Date April	Time: Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
11	218	0	3					Start. 14 Mcal/b-h. S 9 sand.
	222							
	224	0.08				1.05-1.10	70	12.5 Mcal/b-h.
12	238		4				60	1 m S 9 sand added.
	246		5			1.56-1.61	60	1 m S 9 sand added.
	248		6	11.5		1.70-1.73	58	1 m S 9 sand added.
	252							0.5 S 9 sand added.
13	272			12.0		1.70-1.80	61	
14	296			11.5			58	
15	320			11.0		1.60-1.70		
	325	1.35						Off. Compr. stopped.
16	330							On.
	334			10.0		1.60-1.62		
	336	1.42						Off. Gas-air mixture out of control.
	337							On.
	338	1.44						Shut off. Sand did not fluidize. Plug of wet sand in burner tube blown out with 5 kg/cm^2 air.
	341							On.
	346			11.2		1.60-1.65		
18	384			11.2		1.65-1.70	60	
	385							0.5 S 9 sand added.
19	402			11.8		1.75-1.80		
	409	2.29						Off. Gas-air mixture out of control. Could not start against the sand. All sand had to be blown out.
25	580		3					On. S 9 sand.
	584					1.0	60	
26	589		4					1 m S 9 sand added.
	593		5					1 m S 9 sand added.
	600			10.5		1.45-1.48	60	
	604		6					1 m PS sand added.
	605	2.60						14 Mcal/b-h.
	606			11.7				
	607	2.63						Off. Burner casing burned off at cone level, 21.8 m. Pulled burner showed no damage Burner had been on 209 hours and off 180 hours
29	670							T 6 converted to electrical heater 89/91.

Gas-KL 2, B 7

Time: Date April	Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
2	0	0	0			0.35		Start. 10 Mcal/b-h.
	1	0.01						Off when h.i. increased to 11 Mcal/b-h.
	2							On.
	5					0.45		
	7	0.06						Off when h.i. increased to 11 Mcal/b-h.
	8					0.55		On.
	14					0.64		
3	20	0.18				0.74		Off. About 4 m water in burner casing.
	35		1					On. All water except 0.5 m blown out. 14 Mcal/b-h. S 9 sand.
	36					0.75		
4	40					0.75	35	
	42					0.86	38	
	44	0.31						Shut off to blow out all water and sand.
5	75		0			0.60		On.
	75.5		1			0.65		S 9 sand.
	76		2				22	S 9 sand.
	78					0.85	47	
	82					0.90-0.93	62	
6	92					1.00-1.03	66	
	100					0.85-0.95	61	
	101		3			1.05-1.12		S 9 sand.
	110					1.05-1.10	63	
	111		4			1.22-1.28	60	
7	122					1.25-1.37	59	
	123		5			1.41-1.48		S 9 sand.
	130			<10.0		1.40-1.48	61	
8	146			10.3		1.45-1.50	57	
9	174					1.38-1.45	61	
10	190	1.92						Off. Ice in orifice plate. On again easily.
	196			<10.0		1.40-1.45	60	Water at 22 m.
	198		6			1.65-1.69		S 9 sand.
11	222			10.8		1.72-1.78	59	
	224	2.39						12.5 Mcal/b-h.
12	244			11.0		1.68-1.72	60	
	251	2.73						Water at 22 m. No fluidization. Off.
13	266		3					On. All sand blown out and replaced with new S 9 sand.

Time: Date April	Time: Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
13	272			<10.0				
	274		5				39	
14	282						58	S 9 sand.
	286		6	10.7		1.65-1.75		
	296			11.5			58	S 9 sand.
15	320			10.5		1.65-1.70		
	325	3.47						Wet sand.
16	330							Off. Compr. stopped.
	334			<10.0				On.
	336	3.54						Sand did not fluidize.
	337							Off. Gas-air mixture out of control.
	338	3.56						On.
	340							Shut off. No fluidization. Sand plug in burner tube blown out with 5 kg/cm^2 air.
	342							On.
	344							Off a few minutes to blow air through b-tube. No fluidiz.
	346			11.1		1.60-1.70		Off a few minutes to blow air through b-tube. No fluidiz.
17	362			10.8		1.68-1.73	53	Wet sand.
18	385			10.7		1.78-1.82		Dry sand.
19	400	4.31						Shut off. No fluidiz. Burner pulled to blow out all sand. B-tube was dropped when being reinstalled so bottom plate of b-casing was knocked out.
								B-casing was sealed at 31.8 m with rubber packer, cemented 2 times to 31.0 m, filled with S 9 sand to 30.15 m and a piece of 2 1/2" pipe with top and bottom plates to 30.0 m. B-tube was shortened to 8 m with b-tube coupling at 2 m below cone.
30	694		3					On. 14 Mcal/b-h.
	700							S 9 sand.
			4			0.95-1.00	42	S 9 sand.

Time		Heat input total 10^3Mcal	Sand			Pressure kg/cm^2	Temp. Exhaust gas ^{o}C	Remarks
Date April	Hours from start		Amount A m	Fluidiz. B m	Expans. B/A			
30	702					1.10-1.15		
			5	9.4				S 9 sand.
	704					1.60-1.63		
			6	9.2				S 9 sand.
	708	4.50		9.2		1.80-1.85		Water above sand blown out.
								During April: On 343 hours, off 365 hours.
May 1	710			9.0		1.85-1.90		Wet sand. Water blown out.
	714							Wet sand. Water blown out.
	722			10.2		1.60-1.75		Dry sand.
2	749							0.6 m S 9 sand added.
	758			12.1		1.80-1.85		
4	786		4.1	11.8	2.9	1.80-1.92		Water blown out.
	794		5.2					S 9 sand added.
	796	5.73						Off. Gas-air mixture out of control. Could not unlock b-tube coupl Burner pulled and sand blown out.
5	814		3					On. S 9 sand.
	815		4					S 9 sand.
	816		5					S 9 sand.
	817	5.77	6					S 9 sand. 12.5 Mcal/b-h.
	822			11.4		1.65-1.80		
6	846		4.8	12.5	2.6	1.70-1.80	59	
			6.0					S 9 sand.
7	856			10.9	1.8	1.80-1.95	57	
	870			12.5		1.70-1.85	59	
8	894			11.9		1.70-1.80	60	
9	902	6.83						14 Mcal/b-h.
	908		4.0	11.0	2.8	1.55-1.70	60	
			6.0					S 9 sand.
	910	6.95						12.5 Mcal/b-h. Water blown up 3 times.
10	942		5.0	12.0	2.4	1.70-1.80	59	
			6.0					
	952			13.5	2.3	1.80-1.90	61	
11	960							Blew up water in cas.
	968							Blew up water in cas.

Gas-KL 2, B 7

Time Date May	Time Hours from start	Heat input total 10^3Mcal	Sand Amount A m	Sand Fluidiz. B m	Sand Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
13	1013		4.9	13.2	2.7	1.70-1.85	61	
	1014	8.25						Off. Power failure.
	1016		6.0					On. S 9 sand.
	1028			13.9	2.3	1.9 -2.0	62	
14	1051	8.68						Off. Air failure.
15	1063							On. Sand plug in b-tube removed with air before start.
16	1094		5.5 6.0	13.0	2.4	1.8 -1.9	60	
17	1106			13.5	2.3	1.8 -1.95	59	Blew up water from 14m.
	1118							Blew up water from 16m.
19	1152							Blew up water from 16m.
	1154			13.5		1.85-2.0	59	
	1170	10.02						Off. Gas-air mixture out of control.
	1171							On.
20	1184		4.5	13.0	2.9	1.95-2.05	56	
	1187	10.22						Shut off for cleaning of mixing equipment.
	1192		6.0					On.
21	1202			13.0	2.2	2.0 -2.1	59	
22	1245			12.9		1.85-2.0	58	Water and sand plug at 16 m blown out.
23	1254		3.8 6.0	13.1	3.5	1.75-1.9	61	
	1260			15.5	2.6	1.95-2.15	59	Sand plug at 12 m blown up.
	1266							Water blown up.
	1268							Water blown up.
	1270							Water blown up.
24	1274			13.5	3.5	1.80-1.95	58	Sand plug at 12 m removed.
	1283		3.9 6.0	14.5	2.4	1.95-2.15	58	
25	1298			13.0		2.0 -2.15	57	Sand plug removed.
26	1327			14.0		1.95-2.15	58	Sand plug at 12 m blown out.
	1341							Water and sand plut at 15 m removed.
	1346			14.1	3.1	1.95-2.05	58	
27	1354		4.6 6.0	14.7	2.5	2.0 -2.15		
	1360							Sand plug at 15 m removed.

Gas-KL 2, B 7

Time Date May	Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
28	1366							Sand plug at 15 m removed.
	1370			14.5		1.95-2.1	59	
	1379							Sand plug at 13 m.
29	1400			14.0		1.9 -2.05	58	Sand plug at 14 m.
30	1415							Sand plug at 12 m removed.
	1426			12.5		1.8 -1.95	58	
	1432	13.22	3.6	13.0	3.6	1.8 -1.95	60	Smell of pyrolysis gas after the burner was shut off.
								Burner casing leaking slightly, probably at a weld. However, the leakage ended later. The pulled burner was O.K.

Gas-KL 2, B 8

Time Date April	Hours from start	Heat input total 10^3Mcal	Sand Amount A m	Fluidiz. B m	Expans B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
2	0	0	0			0.35		Start. 10 Mcal/b-h.
	1	0.01						Off when h. i. incr. to 11 Mcal.
	2							On. 10 Mcal/b-h.
	5					0.45		
	7	0.06						Off when h. i. incr. to 11 Mcal.
	8					0.57		On. 10 Mcal/b-h.
	14					0.65		
3	20	0.18				0.72		Off. About 4 m water in b-cas.
	35		2					On. All water except 0.5 m blown out. 14 Mcal/b-h. S 9 sand.
	36					0.85		
4	40					0.80	53	
	42					0.80	48	
	44	0.31						Shut off to blow out all water and sand.
5	75		0			0.62		On.
	75.5		1			0.70		S 9 sand.
	76		2			0.83	46	S 9 sand.
	78					0.90	62	
	82					0.93-0.95	68	
6	92					1.10-1.20	55	
	100					0.95-1.00	60	
	101		3			1.08-1.14		S 9 sand.
	110					1.10-1.12	61	
	111		4			1.28-1.30	60	S 9 sand.
7	122					1.30-1.35	63	
	123		5			1.42-1.50		P sand.
	130			11.5		1.30-1.59	67	Wet sand.
	132					1.45-1.58	42	Water bubbling in b-cas.
8	146							Lots of water in b-cas.
	149	1.34						Shut off. Burner pulled. Sand and water blown out.
	155		3					On.
9	160					1.01-1.09	60	
	162		5			1.40-1.50	60	S 9 sand.
10	196			10.8		1.45-1.50	60	
	198		6			1.62-1.68		S 9 sand.
11	222			12.3		1.85-1.91	60	
	224	2.30						12.5 Mcal/b-h.
12	250			10.5		1.80-1.85	61	
	252							0.5 m S 9 sand added.

Gas-KL 2, B 8

Time Date April	Time Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	Sand Fluidiz. B m	Sand Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
13	272			11.5		1.80-1.90	57	
15	320			10.7		1.77-1.80		
	325	3.72						Off. Compr. stopped.
16	329							On.
	334			< 10.0		1.62-1.63		No fluidization. Shut off a few minutes to blow 5 kg/cm^2 air through.
	346			11.2		1.55-1.60		
17	362			11.3		1.70-1.78	58	
19	402			11.8		1.80-1.85		
	409							Off. Gas-air mixture out of control.
	410							On.
	414	4.77						Off. Power off. Could not start against the sand. All sand had to be blown out.
25	580		3					On. S 9 sand.
	584					1.0	60	
	589		4					S 9 sand.
	593		5					S 9 sand.
26	600			10.7		1.48-1.50	62	
	604		6					S 9 sand.
	605	5.08						14 Mcal/b-h.
27	616							No fluidization. Shut off a few minutes to blow air through.
	630			11.8		1.75-1.80	57	
29	668			13.3		1.78-1.85		
30	708	6.52		12.5		1.70-1.80		During April: On 483 hours, off 225 hours.
May 2	748			12.3		1.65-1.75		14 Mcal/b-h.
	749							0.6 m S 9 sand added.
	758			13.1		1.80-1.90		Hard sand plug in b-cas. blown out.
4	786			13.5		1.88-1.98		Water blown out.
	794							1.1 m S 9 sand added.
	798	7.78						Off. Gas-air mixture out of control.
	799							On.
	800			15.1		1.90-2.00		
5	817	8.03						12.5 Mcal/b-h.
	822			13.3		1.70-1.85		

Gas-KL 2, B 8

Time Date May	Hours from start	Heat input total 10^3Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
6	846		4.6 6.0	14.0	3.1	1.70-1.80	55	S 9 sand.
7	856 870			12.6 15.0	2.1	1.75-1.90 1.80-1.95	60 58	
8	894			14.4		1.75-1.85	58	
9	902 908	9.09	4.0 6.0	13.0	3.3	1.55-1.70	60	14 Mcal/b-h.
	910	9.21						S 9 sand. 12.5 Mcal/b-h
10	942 960			13.8 14.5		1.80-1.90 1.8 -1.9	58 59	Sand plug at 17 m removed.
11	976							Sand plug at 16 m blown up.
13	1013 1014 1016 1028	10.51	4.5 6.0	14.1 14.7	3.1 2.5	1.7 -1.85 1.9 -2.05	60 59	Off. Power failure. On. S 9 sand.
14	1051	10.94						Off. Air failure.
15	1063							On. Sand plug in b-tube removed with air before start.
16	1082 1089	11.27		13.9	--	1.8 -1.95		Shut off for inspection Burner tube coupling showed a little leakage Coupling ground.
	1091							On.
17	1112		4.8 6.0	14.6	3.0	1.9 -2.05	59	
	1118			14.8	2.5	2.0 -2.1	58	
19	1154 1170	12.26		14.7		2.0 -2.15	58	Off. Gas-air mixture out of control.
	1171							On.
20	1184 1187	12.46	4.6	14.7	3.2	1.95-2.05	57	Shut off for cleaning of mixing equipment.
	1192		6.0					On. B-tube coupling did not loosen for restart. Burner had to be pulled. S 9 sand in 2 hours.
21	1202			14.0	2.3	2.0 -2.15	59	

Time: Date May	Time: Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
23	1250			15.3		1.95-2.05	57	Water-sand plug at 15 m blown out.
	1260		3.9			1.85-2.05	60	
	1276		6.0	15.7	2.6	2.05-2.15		
	1283							Sand plug at 16 m removed.
	1295							Sand plug at 14 m removed. Sand and water plug blown out.
25	1298			15.3		2.0 -2.2	59	
26	1341							Water and sand at 15 m removed.
27	1346			15.0	3.2	2.0 -2.15	61	
	1350							Water and sand at 15 m removed.
	1354		4.7					
	1360		6.0	16.3	2.7	2.1 -2.2	\	Water and sand at 15 m removed.
28	1370			16.7		2.0 -2.15	58	
	1379							Water and sand blown out.
29	1400			16.5		2.0 -2.15	58	Water and sand blown out.
30	1418			15.7		2.0 -2.15	68	Sand plug at 15 m removed.
	1421	15.32					78	Smell of pyrolysis gases. Burner casing off. Burner tube coupling showed that there had been no leakage at all. A rubber packer was pushed down and became stuck at 22.5 m which is 9.5 above bottom f b-casing or 0.5 m below cone. It was locked here and the gas leakage was stopped. The leakage might have come from the weld seam between 18/8 stainless steel and carbon steel weld at 8.7 m above bottom.

Gas-KL 2, B 9

Time: Date April	Time: Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
2								35° C at 23, 30, 32 m in T 9 B. 9 m long b-tube.
	0	0	0			0.35		Start. 10 Mcal/b-h.
	1	0.01						Off when h. i. incr. to 11 Mcal.
	2							On.
	5					0.45		
	7	0.06						Off when h. i. incr. to 11 Mcal.
	8					0.55		On.
	14					0.65		
3	20	0.18				0.71		60° C at 30 m in T 9 B. Off. About 3.5 m water in b-cas.
	35							On. All water except 1 m blown out. Socktube without net on bottom of b-tube. Burner raised 0.5 m with net above water. 14 Mcal.
	36					0.77		
4	40					0.90	48	
	42					0.85	40	
	44	0.31						Off. Ice in orifice plate.
5	75					0.57		On. All water removed 14 Mcal/b-h.
	75.5		1			0.63		S 9 sand.
	76		2			0.75	18	S 9 sand.
	78					0.84	41	
	82					0.88-0.90	62	60° at 30 m in T 9 B.
6	92					1.00-1.10	56	85° at 30 m in T 9 B.
	93							Off. Unknown reason. Relit.
	100					0.90-0.95	62	
	101		3			1.02-1.07		S 9 sand.
	102							Temp. in T 9 B: 95° C at 23 m, 100° C at 30 m 9 m long b-tube with coupl. 2 m below cone.
	110					0.96-1.01	61	120° C at 30 m in T 9 B.
	111		4			1.15-1.18	61	S 9 sand.
7	122					1.20-1.25	63	T 9 B: 345° at 23 m, 140° at 30 m, 80° at 31.8 m, 40° at 32 m. Burner raised 0.5 m when being checked by pulling it a few mm each time.

Gas-KL 2, B 9

Time		Heat input total	Sand			Pressure	Temp. Exhaust gas	Remarks
Date April	Hours from start	10^3 Mcal	Amount A m	Fluidiz. B m	Expans. B/A	kg/cm^2	°C	
7	123		5			1.35-1.50		P sand.
	130			<10.0		1.40-1.50	63	190° C at 30 m.
	133	1.12						Off. Unknown reason. 1/4" coupl. was unscrewed when trying to loosen b-tube coupl. Burner had to be pulled and all sand blown out. Very wet sand.
8	145		5					On. New S 9 sand.
	146					1.45-1.55	28	
9	160					1.40-1.50	56	
	175							Temp. curve, see Fig. 1.
10	196			10.3		1.50-1.65	62	315° C at 23 m.
	198		6			1.70-1.80		S 9 sand.
11	222			12.0		1.79-1.86	60	310° C at 23 m.
	224	2.23						12.5 Mcal/b-h.
12	240							Temp. curve, see Fig. 1.
	250			11.0		1.80-1.90	59	300° at 23 m.
	252							1 m S 9 sand added.
13	266							Water between 15 and 20 m blown out with air.
	272			11.5		1.85-1.93	60	
15	320			11.5		1.75-1.80	57	Wet sand.
	325	3.49						Off. Compr. stopped.
16	329							On.
	334			11.5		1.75-1.80		Temp. curve, see Fig. 1.
	336	3.58						Off. Gas-air mixture out of control.
	337							On.
17	362			11.5		1.75-1.80		340° C at 23 m.
18	390							Temp. curve, see Fig. 1.
19	402			11.9		1.75-1.85		
	409	4.48						Off. Gas-air mixture out of control. Could not disconnect b-tube coupl. Burner pulled and then blown down in sand with 5 kg/cm^2 air. Could not start against the sand. Sand blown out with air.
25	580		3					On. S 9 sand.
	584					1.08	68	

Gas-KL 2, B 9

Time: Date April	Time: Hours from start	Heat Input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
26	589		4					1 m PS sand added.
	593		5					1 m PS sand added.
	594						63	Water bubbling in b-cas.
	600			12.0		1.40-1.50	51	Dry sand. No water bubbling.
	604		6					1 m PS sand added.
	605	4.79						14 Mcal/b-h.
	609			13.8		1.80-1.85	60	Wet sand. Water bubbling. No temp. on T 9 B. Could not move thermocouple.
27	626	5.08						Shut off. No fluidiz. Lots of water. Water and some sand blown out with air.
	627							On.
	630							1 m PS sand added.
	632			11.4		1.45-1.60		
28	642							Water at 18 m blown up with air.
	644							Water at 17 m blown up with air.
	654			12.0		1.68-1.80		Wet sand.
29	660							Water blown up with air.
	662			11.8		1.60-1.70		Water blown up with air.
	665							Water blown up with air.
	668			11.9		1.60-1.70		Wet sand.
	669							Water blown up with air.
29	672	5.71						Off. B-casing and T 9 B casing burned off. Could not pull burner. It was unscrewed at 1/4" coupl. Burner had been on 435 hours and off 237 hours.
May 4	790							T 9 converted to electrical heater 89/88.

Gas-KL 2, B 10

Time Date April	 Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	 Fluidiz. B m	 Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
2	0	0	0			0.35		Start. 10 Mcal/b-h.
	1	0.01						Off when h. i. incr. to 11 Mcal.
	2							
	5					0.50		On.
	7	0.06						Off when h. i. incr. to 11 Mcal.
	8					0.60		
	14					0.65		On.
3	20	0.18				0.68		Off. About 3.5 m water in b-cas.
	35							On, All water except 1 m blown out. 14 Mcal/b-h.
	36					0.75		
4	40					0.90	55	
	42					0.86	61	
	44	0.31						Off. Ice in orifice plate.
5	75		0			0.60		On. All water blown out.
	75.5		1			0.70		S 9 sand.
	76		2			0.90	37	S 9 sand.
	78					0.89	60	
	82					0.92-0.94	68	
6	92					1.10-1.20	58	
	100					0.94-0.97	59	
	101		3			1.02-1.06		S 9 sand.
	110					1.10-1.18	60	
	111		4			1.36-1.38		S 9 sand.
7	122					1.35-1.47	59	
	123		5			1.45-1.50		1 m P sand added.
	130			<10.0		1.52-1.60	59	
8	146					1.55-1.60	55	Water at 21.5 m.
10	196			<10.0		1.40-1.50	62	Water at 22.0 m.
	198		6			1.62-1.70		1 m P sand added.
	200					1.60-1.68	45	Water bubbling.
11	222	2.37						Off. B-casing and supply tube at centralizers burned off. Only supply tube pulled.
								Burner was on 174 hours and off 48 hours.
.2	240							T 10 converted to electrical heater 89/87.

Gas-KL 2, B 11

Time: Date April	Time: Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
12	242	0	3					Start. 12.5 Mcal/b-h. S 9 sand. Socktube with 0.5 mm screen on b-tube.
	249	0.09						Off. B-tube plugged with sand. Socktube removed. Sand blown out.
25	581		3					On. S 9 sand.
	584					0.80	25	Water bubbling.
26	594					1.00	68	Water bubbling.
	598		4					1 m S 9 sand added.
	599		5					1 m S 9 sand added.
	600			10.3		1.38-1.41	60	
	604		6					1 m PS sand added.
	605	0.39						14 Mcal/b-h.
	609			11.1		1.75-1.80	63	
27	630			11.4		1.80-1.90	58	
28	642			11.1		1.75-1.82		Wet sand.
	658			12.4		1.80-1.88		Dry sand.
29	662			12.1		1.80-1.85		Wet sand.
	670	1.30						Off. Unknown reason. Could not loosen b-tube coupling. Burner pulled. Sand except 1 m blown out with air.
	676		1					On.
	678		2					S 9 sand.
	680		3			1.20-1.30	59	-"-
	681		4					-"-
	682		5					-"-
30	684		6					PS sand.
	688			11.8		1.50-1.60	56	
	708	1.74		12.2		1.65-1.78		During April: On 128 hours, off 338 hours.
May 2	748			12.0		1.70-1.75		14 Mcal/b-h.
	749							0.6 m PS sand added.
	758			12.4		1.80-1.82		
3	772			12.5		1.75-1.85		
	773							0.4 m PS sand added.
4	786		6.0	12.5	2.1	1.90-1.93		
	794		7.1					1.1 m S 9 sand added.
	796	2.97						Off. Gas-air mixture out of control. It was now found that too much sand had been added. The sand was above b-tube coupling, so it could not be locked. Burner pulled and sand blown out. B-tube coupl. was O.K.

Time: Date May	Time: Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
5	817		3					
	817.5		4					On. S 9 sand. 12.5 Mcal/b-h.
	818		5					S 9 sand.
	819		6					-"-
	822			11.8		1.70-1.80		-"-
6	846		5.3	12.5	2.4	1.80-1.90	60	
			6.0					S 9 sand.
7	856			12.7	2.1	1.70-1.85	59	
	870			12.5		1.70-1.85	60	
8	894			11.7		1.70-1.75	60	
9	902	4.03						14 Mcal/b-h. Water blown up 2 times.
	908		5.2	12.2	2.4	1.70-1.80	59	
			6.0					
	910	4.14						S 9 sand. 12.5 Mcal/b-h. Water blown up.
10	942		5.8	12.0	2.1	1.75-1.80	61	
			6.0					S 9 sand.
	952			12.3	2.1	1.85-1.90	60	
13	1013		5.4	12.3	2.3	1.80-1.85	61	
	1014	5.44						Off. Power failure. Burner pulled for insp. Burner tube coupl. had been leaking. Coupl. ground.
	1024		6.0					On.
	1028			12.5	2.1	1.85-1.95	60	
14	1051	5.78						Off. Air failure. Burner pulled. Hole was erroded out by untight b-tube coupl. Coupl. ground and hole filled with weld.
16	1089		6.0					On.
	1094			13.1	2.2	1.8 -1.9	58	
17	1114		5.2	14.2	2.7	1.9 -2.05	60	
			6.0					
19	1154			13.3	2.2	2.05-2.15	58	
	1160	6.67						Shut off for installing 1.5 m coupling tube.
	1168							On.
	1170	6.69						Off. Gas-air mixture out of control. Could not separate burner tube parts because coupl tube was too light. Burner pulled.

Time Date May	Hours from start	Heat input total 10^3Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
20	1185		6.0					On.
	1187	6.90						Shut off for cleaning of mixing equipment.
	1192							On.
21	1202			14.0	2.3	2.0 -2.1	58	
22	1245			14.1		2.0 -2.05	55	Water blown up.
23	1260		7.0	14.1	2.0	2.05-2.1	57	
	1262							Water blown up.
	1266							" " "
24	1274			13.8		2.0 -2.05	58	
	1283		7.0	13.9	2.0	2.1 -2.15	58	
	1290							Water blown out at 17 m.
	1295							Water and sand plug removed.
25	1298			14.3		2.0 -2.1	57	
	1305							Sand plug at 14 m removed.
26	1341							Sand and water plug removed.
27	1354		6.0	13.7	2.3	2.0 -2.1	57	Sand and water plug removed.
	1360							Sand plug at 11 m removed.
28	1368							Sand plug at 11 m removed.
	1370			14.0		1.95-2.05	57	
	1376							Sand plug at 14 m removed.
29	1400			14.3		1.9 -2.0	57	Sand plug at 14 m removed.
30	1415							Sand plug at 12 m blown out.
	1432	9.71	4.7	13.7	2.9	1.85-1.95	58	Burner shut off. Pulled burner showed no damage. There had not been any leakage through b-tube coupling with coupling tube.

Gas-KL 2, B 12

Time		Heat input total	Sand			Pressure	Temp. Exhaust gas	Remarks
Date April	Hours from start	10^3 Mcal	Amount A m	Fluidiz. B m	Expans. B/A	kg/cm^2	°C	
2	0	0	0			0.35		Start. 10 Mcal/b-h.
	1	0.01						Off when h. i. incr. to 11 Mcal.
	2							On. 10 Mcal/b-h.
	5					0.40		
	7	0.06						Off when h. i. incr. to 11 Mcal.
	8					0.50		On. 10 Mcal/b-h.
	14					0.62		
3	20	0.18				0.71		Off. About 3.5 m water in b-cas.
	35							On. All water except 1.0 m blown out. 14 Mcal/b-h.
	36					0.68		
4	40					0.72	52	
	42					0.79	64	
	44	0.31						Off. Ice in orifice plate. Burner pulled and water blown out. B-tube was dropped when it was sunk down so it knocked out bottom plate of b-cas. B-cas. was sealed at 32.0 m with rubber packer, cemented 2 times up to 31.1 m, filled with S 9 sand to 30.15 m and a 2 1/2" pipe with top and bottom plates placed up to 30.0 m. B-tube was shortened to 8 m with b-tube coupl at 2 m below cone.
14	287		3					On. 12.5 Mcal/b-h. S 9 sand.
	296		4					-"-
	300		5					-"-
15	304			10.8		2.00-2.10		Water bubbling.
	310			11.1		1.90-1.95	60	
	320	0.72				2.05		Shut off. B-tube plugged with wet sand. B. pulled and all sand blown out.
25	581		3					On. S 9 sand.
	584					0.91	68	
26	589		4					S 9 sand.
	593		5					1 m PS sand.

Gas-KL 2, B 12

Time: Date April	Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
26	600			9.8		1.45-1.52	61	
	604		6					
	605	1.02						1 m PS sand.
								14 Mcal/b-h.
	609			9.5		1.70-1.80		
27	630			9.3		1.80-1.85		
	632							Blown out water with air.
28	642			12.5		1.80-1.90		Dry sand.
	658			10.0		1.80-1.93		Wet sand.
29	663							Blown out water with air.
	668			11.2		1.80-1.85		Wet sand.
30	688							Blown out water witha air.
	692							Blown out water with air.
	708	2.46		10.2		1.75-1.85		Dry sand. During April: On 187 hours, off 521 hours.
ay 2	748			10.1				14 Mcal/b-h.
	749							0.6 m PS sand added.
	758			10.8		1.80-1.85		
3	770			10.2		1.75-1.80		Sand plug in b-cas. blown out.
	772							0.8 m S 9 sand added.
	774			10.5		1.70-1.80		Sand plug blown out.
4	784			11.4		1.85-1.95		Water blown out.
	786			11.0		1.82-1.92		" " " .
	794							1.1 m S 9 sand added.
	798	3.72						Off. Gas-air mixture out of control.
	799							On.
	800			12.5		1.90-2.05		
5	817	3.97						12.5 Mcal/b-h.
	822			11.4		1.70-1.85		
6	846	4.33	6.0	9.8	1.6	1.40-1.60	45	Shut off, because sand test pipe was sheck. Burner had to be pulled to get test pipe up. Most of the sand had to be removed.
	848		6.0					On. S 9 sand added in 2 hours.

Gas-KL 2, B 12

Time		Heat input total 10^3 Mcal	Sand			Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
Date May	Hours from start		Amount A m	Fluidiz. B m	Expans. B/A			
7	856			10.2	1.7	1.75-1.85	58	
	870			11.0		1.75-1.90	62	
8	894			11.5		1.60-1.75	60	
9	902	5.01						14 Mcal/b-h. Water blown out 2 times.
	908		4.0	11.8	3.0	1.70-1.80	52	
			6.0					S 9 sand.
	910	5.12						12.5 Mcal/b-h.
10	942			11.6		1.70-1.80	58	
11	975							Temp. inside b-casing: 85° C at 16 m and 320° C at 18 m.
12	985			10.9		1.75-1.9	58	Sand plug removed.
	990			10.5		1.75-1.9	59	Water and sand at 16 m blown up.
	992	6.15						Shut off for inspection. B-tube coupl. leaking Ground. All sand and lots of water blown up.
	996		6.0					On. S 9 sand.
	1000			13.5	2.3	1.8 -1.9	62	
13	1010							Sand plug removed.
	1013		4.2	13.5	3.2	1.8 -1.9	60	
	1014	6.37						Off. Power failure.
	1016		6.0					On. S 9 sand.
	1028			15.0	2.5	1.9 -2.05	58	
14	1034			15.5		1.9 -2.05	59	
	1040			13.0		1.9 -2.0	61	
	1051	6.81						Off. Air failure. Later it was found that burner casing was leaking. Could only recover supply tubes.

Time		Heat input total 10^3 Mcal	Sand			Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
Date April	Hours from start		Amount A m	Fluidiz. B m	Expans. B/A			
2	0	0	0			0.35		Start. 10 Mcal/b-h.
	1	0.01						Off when h. i. incr. to 11 Mcal.
	2							On. 10 Mcal/b-h.
	5					0.50		
	7	0.06						Off when h. i. incr. to 11 Mcal.
	8					0.60		On. 10 Mcal/b-h.
	14					0.69		
3	20					0.77		13 Mcal/b-h.
	24	0.23						Off. About 5 m water in b-casing.
	35					1.20		Could not start it, because water was above b-tube coupling.
5	75					0.60		On. 14 Mcal/b-h. Burner had been pulled and all water blown out.
	75.5		1			0.70		S 9 sand.
	76		2			0.81	16	-"-
	78					0.93	50	
	82					0.94-0.99	68	
6	92					1.10-1.13	60	
	100					0.90-0.95	60	
	101		3			1.10-1.15		S 9 sand.
	110					1.08-1.12	60	
	111		4			1.25-1.30		S 9 sand.
7	122					1.20-1.30	63	
	123		5			1.48-1.54		S 9 sand.
	130			10.8		1.53-1.60	61	Wet sand.
9	168							Off. Unknown reason. Relit in a few minutes.
10	190	1.84						Off. Ice in orifice plate. Could unlock b-tube coupl. first after 2 hours. Started against the sand.
	196			<10.0		1.38-1.45	67	On. Water at 22 m.
	198		6			1.60-1.63	65	S 9 sand. Off. Relit immediately.
11	207	1.99						Off. Water in b-casing.
	208							On.
	211	2.05						Off. Ice in orifice plate.
	212							On.
	214							Off. Ice in orifice plate. Relit immediately.

Gas-KL 2, B 13

Time Date April	Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
11	222			12.3		1.78-1.85	61	
	224	2.24						12.5 Mcal/b-h.
12	250			10.3		1.80-1.85	59	
	252							1 m S 9 sand added.
13	272			11.1		1.78-1.82	59	
15	320			11.7		1.77-1.82	57	
	325	3.50						Off. Compr. stopped.
16	330							On.
	334			11.0		1.68-1.70		
	336	3.64						Off. Gas-air mixture out of control.
	337							On.
	338	3.65						Shut off. No fluidiz. Blown air through burner
	339							On.
	346			11.6		1.60-1.70		
18	385			12.2		1.78-1.82	60	
19	409	4.52						Off. Gas-air mixture out of control. Could not loosen b-tube coupl. Burner had to be pulled. Could not start against 3 m sand. Burner pulled again and all sand blown out.
25	581		3					On. S 9 sand.
	584					1.25	18	Water bubbling.
26	594					1.50	45	" "
	598	4.74						Off. No fluidiz. Water blown up with air through burner.
	599							On.
	602	4.77						Off. No fluidiz. Water blown up with air through burner.
	603							On.
	605	4.81						14 Mcal/b-h.
	606		4					S 9 sand.
	607	4.84						Shut off. No fluidiz. Burner pulled and all sand blown out. Could not restart because one compr. had to be shut off.
29	676		3					On. S 9 sand.
	680		4					S 9 sand.

Gas-KL 2, B 13

Time Date April	Time Hours from start	Heat input total 10^3 Mcal	Sand Amount A m	Sand Fluidiz. B m	Sand Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
29	681		5					
	682							S 9 sand. Water at 20 m blown up with air. Water at 16 m blown up with air. Still water bubbling at 20 m.
30	686	4.98						
	708							Shut off. Lots of water. During April: On 375 hours, off 333 hours.
May 3	766		3					On. 14 Mcal/b-h. S 9 sand.
	767		4					S 9 sand.
	768		5					-"-
	770		6					-"-
	772			13.4		1.65-1.75		
	776							Sand plug in b-casing blown out.
4	782			12.4		1.87-1.93		Water blown out.
	786			12.3		1.85-1.90		" " "
	794							
	796							1.1 m S 9 sand added.
	798	5.43						Off. Gas-air mixture out of control. On after a few minutes.
	799							Off. Gas-air mixture out of control.
	800			13.2		1.85-2.00		On.
5	817	5.68						
	822			11.9		1.70-1.80		12.5 Mcal/b-h.
	826							Water blown up.
6	846		6.5	12.3	1.9	1.80-1.90	59	
7	856			12.5		1.80-1.90	57	
	870			13.0		1.80-1.90	58	
8	894			12.4		1.65-1.75	61	
9	902	6.74						14 Mcal/b-h.
	908		4.7	12.1	2.6	1.60-1.80	58	
			6.0					S 9 sand.
	910	6.85						12.5 Mcal/b-h.
10	942			13.3		1.75-1.85	57	
13	1013		5.2	12.8	2.5	1.8 -1.9	58	
	1014	8.15						Off. Power failure. Burner pulled for insp. B-tube coupl. was leaking. Ground.
	1021		6.0					On. S 9 sand.
	1028			13.5	2.3	1.9 -2.05	61	

Time Date May	Hours from start	Heat input total 10^3Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
14	1051	8.53						Off. Air failure.
15	1063		6.0					On. Sand plug in b-tube removed with air before start.
16	1094	--	5.0	13.5	2.7	1.8 -1.9	57	
			6.0					
17	1106			14.0	2.3	1.9 -2.0	58	Water blown up from 17 m.
18	1130							" " " " "
19	1154			14.7		2.05-2.15	59	
	1170	9.87						Off. Gas-air mixture out of control.
	1171							On.
20	1184		5.6	14.9	2.7	1.85-2.0	58	
	1187	10.07						Shut off for cleaning of mixing equipment.
	1192		6.0					On.
21	1202			14.5	2.4	2.0 -2.15	58	
23	1254							Sand and water plug at 16 m removed.
	1260		5.5	15.0	2.7	2.0 -2.1	61	
			6.0	15.2	2.5	2.0 -2.1		
24	1274			14.9		1.95-2.1	60	
	1298			15.2		2.05-2.15	58	
26	1341							Water blown out.
27	1346							Sand and water plug at 14 m removed.
	1350							
	1354		4.7	14.5	3.1	1.9 -2.1	58	
			6.0	15.0	2.5	2.05-2.15		
28	1373							Sand and water plug at 14 m removed.
	1377							Sand and water plug at 14 m removed.
29	1400			15.0		2.0 -2.15	58	Sand and water plug at 14 m removed.
30	1426			14.2		1.95-2.05	57	
	1428	13.02					75	Burner casing off. B-tube coupl. showed a little leakage, otherwise burner was undamaged. With a rubber packer it was found that the casing was leaking at the weld 22.0 m below ground surface or 10.7 m above bottom of burner casing.

Time		Heat input total 10^3 Mcal	Sand			Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
Date April	Hours from start		Amount A m	Fluidiz. B m	Expans. B/A			
2								20° C at 24 and 30 m in T 14 B. 8 m b-tube with b-tube coupl. 2 m below cone.
	0	0	0			0.35		Start. 10 Mcal/b-h.
	1	0.01						Off when h. i. incr. to 11 Mcal
	2							On. 10 Mcal/b-h.
	5					0.45		
	7	0.06						Off when h. i. incr. to 11 Mcal.
	8					0.55		On.
	14					0.60		85° C at 24 m, 70° C at 30 m.
3	20	0.18				0.73		Off. About 4 m water in b-casing.
	35							On.. All water except 0.5 m blown out. 14 Mcal/b-h. S 9 sand.
	36					0.74		
4	40					0.85		60° C at 30 m.
	41							Off. Relit easily.
	42							" " "
	44	0.31						Off. Ice in orifice plate. All water blown out with air.
5	75					0.60		On.
	75.5		1			0.70		S 9 sand.
	76		2			0.85	18	
	78					0.94	45	
	82					0.95	61	
	84							Off. Easily relit.
6	90							" " "
	91	0.53						Off.
	93							On.
	94	0.54						Off.
	97							On.
	98	0.56						Off.
	99							On.
	102							75° C at 24 m, 60° C at 30 m.
	110					0.98-1.00	63	80° C at 30 m.
	111		3			1.02-1.08		S 9 sand.
7	122					1.30-1.40	62	320° C at 23 m, 170° C at 30 m, 160° C at 31.5 m, 80° C at 31.8 m, 40° C at 30 m.
	123		4			1.38-1.47		S 9 sand.
	130					1.40-1.55	61	240° C at 30 m.
	133							Off. Easily relit.

Gas-KL 2, B 14

Time: Date April	Time: Hours from start	Heat input total 10^3 Mcal	Sand: Amount A m	Sand: Fluidiz. B m	Sand: Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
8	141	1.15						Off. B-tube plugged by wet sand.
	143							Removed with air.
	146			<9		1.45-1.55	60	On. 230° C at 30 m. Water at 22.5 m.
	149	1.23						Off. The burner had continously been raised 0.5 m when being checked by pulling it a few mm each time. Could not get burner down with 5 kg/cm^2 air.
	152							On.
9	160							
	161		5			1.30-1.40	59	220° C at 30 m.
	175					1.35-1.45	59	S 9 sand. See temp. curve on Fig. 1.
10	196			11.3				
	198		6			1.40-1.50	60	350° C at 24 m.
11	222					1.60-1.65	59	S 9 sand.
	224	2.24		11.9		1.80-1.85	59	350° C at 24 m. 12.5 Mcal/b-h.
	240							See temp. curve on Fig. 1.
12	250			10.5				
	252					1.80-1.85		
14	296			11.5				1 m S 9 sand added.
15	320			13.0			59	
	325	3.50				1.65-1.70		Water blown up with air.
16	329							Off. Compr. stopped.
	346			11.8		1.60-1.70		On. Water blown up with air. 440° C at 24 m.
17	361	3.90						Burner casing and T 14 B casing burned off. Could only recover supply tube Burner had been on 298 hours and off 63 hours.
20	435							T 14 converted to electrical heater 90/88.

Gas-KL 2, B 15

Time Date April	Time Hours from start	Heat input total 10^3Mcal	Sand Amount A m	Sand Fluidiz. B m	Sand Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
2	0	0	0			0.35		Start. 10 Mcal/b-h.
	1	0.01						Off when h. i. incr. to 11 Mcal.
	2							On. 10 Mcal/b-h.
	5					0.50		
	7	0.06						Off when h. i. incr. to 11 Mcal.
	8							On. 10 Mcal/b-h.
	14					0.54		
						0.61		
3	20					0.76		13 Mcal/b-h.
	24	0.23						Off. About 4 m water in b-casing.
	35							On. 14 Mcal/b-h. No water blown out.
	36							
	40					0.90		
	42					1.00	68	
						1.00	74	
	44	0.36						Shut off to pull burner and blow out all water. When burner was sunk down, it was dropped and knocked out bottom plate of b-casing. It was sealed with rubber packer at 31.5 m, cement to 30.8 m, sand to 30.15 m and 2 1/2" pipe with top and bottom plates to 30.0 m. B-tube was shortened to 8 m with b-tube coupling 2 m below cone.
14	290		3					On. S 9 sand.
	296		4					S 9 sand.
	300		5					-"-
15	304			9.8			50	Water in b-casing.
	320	0.78				2.05		Shut off. No fluidiz. Plug of wet sand in b-tube. Burner pulled and all sand and water blown out.
25	581		3					On. 12.5 Mcal/b-h. S 9 sand.
	584					1.0	63	
26	589		4					1 m PS sand added.
	593		5					" -"- "
	600			8.7		1.35-1.45	60	
	604		6					" -"- "
	605	1.08						14 Mcal/b-h.
	609			10.0		1.80-1.85	58	

Gas-KL 2, B 15

Time Date April	Hours from start	Heat input total 10^3Mcal	Sand Amount A m	Fluidiz. B m	Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas ^oC	Remarks
28	642			11.8		1.75-1.80	60	
29	670	1.99						
	671							Off. Unknown reason.
	672							On. Plug of sand in burner casing removed with air. 1.1 m PS sand added.
30	708	2.51		10.5		1.65-1.75		During April: On 187 hours, off 521 hours.
May 1	710			10.5		1.55-1.60		Hard sand plug at 16 m blown out.
2	748			9.6		1.60-1.75		
	749							0.6 m SP sand added.
	752	3.13						Shut off. No fluidiz. Burner pulled and sand blown out. Hole 1 x 5mm erroded out 10 mm above b-tube coupling because of gas leakage through coupling. The top centralizers on bottom part of b-tube was 1.2 m below b-tube coupling.
4	790		3					On with new b-tube coupling. S 9 sand.
	791		4					S 9 sand.
	792		5					-"-
	794		6					-"-
	796							Off. Gas-air mixture out of control. On after a few minutes.
	798	3.24						Off. Gas-air mixture out of control.
	799							On.
	800			12.7		1.80-2.00		
5	817	3.49						12.5 Mcal/b-h.
	822			11.5		1.70-1.80		
6	846		6.0	11.3	1.9	1.70-1.80	60	
7	856			10.9		1.70-1.85	61	
	870			12.5		1.75-1.85	59	
8	878	4.25						Off. Unknown reason.
	879							On.
	894			11.5		1.70-1.80	60	
	902	4.54						14 Mcal/b-h.
	908		5.5	12.3	2.2	1.75-1.80	59	
			6.0					S 9 sand.

Gas-KL 2, B 15

Time Date May	Time Hours from start	Heat input total 10^3Mcal	Sand Amount A m	Sand Fluidiz. B m	Sand Expans. B/A	Pressure kg/cm^2	Temp. Exhaust gas °C	Remarks
9	910	4.65						12.5 Mcal/h-h.
10	942			12.6		1.60-1.70	60	
13	1013		5.9	12.7	2.2	1.75-1.85	60	
	1014	5.95						Off. Power failure.
	1016		6.0					On. S 9 sand.
	1028			14.0	2.3	1.9 -2.0	61	
14	1051	6.39						Off. Air failure.
15	1063							On. Sand plug in b-tube removed with air before start.
16	1094		5.4 6.0	13.0	2.4	1.85-1.95	60	
	1106			13.5	2.3	1.85-1.95	60	
19	1154			14.0		1.95-2.05	58	
	1170	7.73						Off. Gas-air mixture out of control.
	1171							On.
20	1184		5.9	14.0	2.4	1.8 -2.0	55	
	1187	7.93						Shut off for cleaning of mixing equipment.
	1192		6.0					On.
21	1202			14.5	2.4	1.95-2.1	59	
23	1260		5.8 6.0	14.5	2.5	1.95-2.05	59	
24	1274			14.8	2.5	1.9 -2.0	58	
25	1298			14.5		2.0 -2.1	59	
27	1346			14.7	2.5	1.9 -2.0	58	
	1354		5.9 6.0	14.9	2.5	2.0 -2.1		
29	1400			14.5		1.95-2.05	58	
30	1432	10.93	5.9	14.5	2.5	1.9 -2.05	59	Burner shut off. Only a very little leakage through b-tube coupling.

Report on LINS Burner Test Gas-KL 2

May, 1960

Summary

The Gas-KL 2 test was shut down and finished May 30th at 1,432 hours from start because five of the remaining eight burner casings burned off, probably at weak casing welds. The burners had been working quite satisfactorily. The sand expansion increased and the heat distribution was as good as expected. However, there were still difficulties with some condensing of the combustion water, and clogging of the sand to sand plugs at the top of the fluidized bed. The burner tube coupling is still another weak point, but a promising improvement was made. It is intended to continue with a third test of five burners where 89 x 3.25 mm (3.50" x 0.13") burner casings of carbon steel will be used in one length without any joint welds.

Operation

The test continued with the burners B 2, 3, 7, 8, 11, 12 and 15 and also with B 13 which was restarted May 3rd at 766 hours. 3 m S 9 sand was added at the start of B 13 and the sand was increased to the normal amount of 6 m within 4 hours, thus much faster, than previously. The heat input was kept at 14 Mcal/b-h (56,000 BTU/b-h) until 817 hours, when it was lowered to 12.5 Mcal/b-h (50,000 BTU/b-h) to decrease the sand loss. B 7, 12 and 15 had 2 m of their bottom parts of the burner casings cemented and were running with 8 m (26'3") long burner tubes. The other burners still consisted of 10 m (32'10") long burner tubes.

The test was shut down the following five times which amounted to 21 hours, 2 hours for power failure and 19 hours for control failure and maintenance on the mixing equipment.

Hours from start	Hours off	Reason
798	1	Gas-air mixture failure
1,014	2	Power off
1,051	12	Air failure
1,170	1	Gas-air mixture failure
1,187	5	Maintenance on mixing equipment

During the operation and immediately after the test shut-downs some of the burners were shut off during a total time of 206 burner hours. This was due to the below listed causes which also include the removal of condensed-water and sand plugs in the burner casing above the cone level without shutting off the burner. (The symbols are the same as used in the April report of 1960.)

C. Burner pulled because the burner tube coupling could not be unlocked after a shut-down.

E. Water and sand plug removed in burner casing with air. (The burner was not shut off.)

F. Unknown reason.

G. Burner tube coupling damaged.

H. Miscellaneous shut-offs.

These events occurred the following times:

Burner	C	E	F	G	H	
B 2		14		1	1	
B 3		4				
B 7	1	22				
B 8	1	14		1		
B 11	1	15		2	2	
B 12		9		1	1	
B 13		12		1	1	
B 15		1	1	1		
Amount hours off	31	0	1	84	90	= 206

The most serious cases of these incidents are the E and G ones.

Despite the sand usually was fluidizing all right, the water in the flue gases condensed in the burner casing at the top of the expanded sand bed, clogged the finer sand particles and formed sand plugs. Some of the water was then collected on these sand plugs and a bubbling sound was heard when the gas went through this water. The water and the sand plugs were easily blown up with air through a one inch rubber hose which was sank down to the sand plugs. The

burners did never have to be shut off, when this was performed. As shown above, this was done only one time in B 15. For some unknown reason the temperature in this burner casing above the fluidized sand level was about 20 % higher than in the others therefore the water did not condence. However, at the top of the casing the temperature was the same, about 60°C, in all the burners. B 3 and B 12 did not either give so much trouble with the water condensation, but these burners were not in operation so long time.

The weakest part of the burner is still the burner tube coupling. As shown above, six of the burners had to be shut off because of damaged couplings. They did not tighten well enough so a part of the hot flue gases went through the coupling. Together with the sand a severe erosion occurred on the top of the coupling part, which in B 11 and B 15 resulted in holes through the top part of the burner tube about one inch above the coupling. B 15 was supplied with a new coupling, while the hole in B 11 was filled with weld and the conical coupling surfaces were ground. The obtained cavities on the other couplings were also filled with weld and the conical parts ground down to a smooth surface. The cause to this leakage might have been a thermal tension on the coupling and a simultaneous bending of the two burner parts so the pressure on the coupling surfaces became uneven, whereafter the flue gases could leak out. In B 2 and B 11 attempts were made to stabilize the coupling by inserting a 1.5 m (4'11") long 25 x 2 mm (0.99" x 0.08") tube inside the burner tube, welded to the top part of the burner tube, 0.25 m (10") above the coupling. Because the annulus space between this coupling tube and the burner was only about 0.5 mm (0.02"), it was impossible to get this tube inside the bottom part of the burner tube after the usual way of burner lighting. Therefore, a hole with a diameter of 20 mm (0.8") was drilled on the coupling tube 1.3 m (4'3") below its top. When the burner was relit, the burner tube was lifted 1.3 m so the hole through the coupling tube came just above the bottom part of the burner tube coupling while about 0.2 m (8") of the coupling tube still was inside the bottom part of the burner tube. At the relighting the flame went into the burner and up to the cone through the hole of the coupling tube. Then the top part of the burner could be sunk down and the coupling locked. The coupling tube stabilized the burner tube coupling and also with the about one meter long narrow annular passage to the coupling diminished the risk of gas leakage. The described coupling tube was installed in B 2 and B 11 at 1,140 and 1,168 hours resp. The tube was made of carbon steel because no other quality was available at the time being. Despite the severe

corrosion the gas leakage through the coupling was much less than earlier, which resulted in an increase of the sand expansion.

Besides the three times when the burner tube couplings could not be unlocked after a shut-down, there were no difficulties in restarting the burners against the sand except after the longest shut-down of 12 hours. At that time, air had to be blown through the burners before the lighting, because the sand had partially plugged the bottom of the burner tubes.

B 3 burner casing burned off at 902 hours. Even if the burner was stuck in the casing so only the supply tube could be pulled, the failure was probably due to a broken casing weld at 8 m below ground surface, because it was impossible to get a rubber packer by at this depth.

After the test shut-down at 1,051 hours the B 12 burner casing began to leak pyrolysis gases. Only the supply tube could be pulled and the cause to the failure was probably a bursted weak casing weld.

Between 1,421 and 1,428 hours the burner casings of B 2, B 8 and B 13 burned off although they had been working fine. The burners could be pulled. They were undamaged except some signs of a little gas leakage through the burner tube coupling. With rubber packers it was found that the casings were off at the welds, placed at 18 m, below 9.5 m and at 10.7 m in resp. burners. In B 13 it was proved that the leakage was at the upper weld of the stainless part of the burner casing and in B 8 it was probably at the lower end of the stainless steel joint.

Because only B 7, B 11 and B 15 were intact the test was shut down at 1,432 hours. At the same time B 7 showed leakage of pyrolysis gases, but it ceased later.

The following table shows the amount of hours the burners were off during May and the total supplied net heat input during May and from the start.

Burner No.	On, hours	Off, hours Shut-downs	Cases F, G, H	Heat input, net during May 10^3 Mcal	10^6 BTU	total from start 10^3 Mcal	10^6 BTU
B 2[1)]	690	21	3	8.80	35.0	12.95	51.5
B 3[1)]	194	1	0	2.57	10.2	7.57	30.1
B 7	686	21	17	8.72	34.6	13.22	52.5
B 8[1)]	690	21	2	8.80	35.0	15.32	60.9
B 11	627	35	62	7.97	31.7	9.71	38.6
B 12[1)]	334	3	6	4.35	17.3	6.81	27.1
B 13[1)]	636	21	63	8.04	31.9	13.02	51.7
B 15	664	21	39	8.42	33.4	10.93	43.4

1) Burner casing off.

The summary of test data are shown on Tables 1 and 2. The complete test data for each burner are not included in the report but they will be available later.

Sand fluidization

It was found that the sand height of the settled bed could be determined without shutting off the burner. The heat input was first decreased so the pressure drop through the burner was only about 0.5 - 0.6 kg/cm^2 (7 - 8 psig). This corresponded to such a low heat input that the sand did not fluidize, the sand bed only expanded about 0.1 m (4"). Then a 1/4" rod iron 0.7 m (2 feet) long was sunk down to the sand in a taped wire. After it had been pulled the heat input was increased to normal value. The reading took about one minute and the measuring could be done so the heat input was decreased only for about 20 seconds. It was found that the burner could even be completely shut off and be relit by itself after such a short shut-off time.

Table 3 is a summary of the fluidization data and shows the ranges of the settled and fluidized beds and the expansion values and the average of the fluidized beds during three different times, i.e. from 708 to 817 hours when the heat input was 14 Mcal/b-h (56,000 BTU/b-h), from 817 to about 1,100 hours when there were difficulties with leaking burner tube couplings, and until the end of the test when the burners usually were working all right except for some difficulties with condensing water.

The sand data show that the sand expansion increased even after the heat input

was decreased from 14,000 to 12,500 BTU/b-h.

The heat was distributed higher and higher up in the casings so less water condensed and hindered the sand expansion. It is interesting that there was only a slight difference in the expanded sand height between the 8 och 10 m long burner tubes. The average of the expanded sand heights for these burners excluding B 3 was 14.1 and 14.7 m resp. (46'2" and 48'2") during the last 300 hours.

At the end of April different amounts of a sieved packing sand, called PS sand was tried in five burners. Two of these burner casings burned off in April and B 15 had to be pulled when also the sand was blown out and then replaced with S 9 sand. The remaining two burners B 11 and B 12 contained 1 and 2 m PS sand, added after 5 and 4 m S 9 sand resp. It was thought that this somewhat smaller sand size should give a larger sand expansion then the L 9 sand. For B 11 there was no difference and B 12 showed less good fluidization. Instead, the finer particles clogged easier with the condensed water in the burner casing, therefore only L 9 sand was used after 794 hours.

The sand size of the fluidized sand was determined at two times. The sieve analyses are shown on Table 4. The first sand samples were taken from the top part of the fluidized bed at about 970 hours, one sample from B 2 and one from the other burners together. The difference in average sand size was negligable and was about 80 % of the original sand size. After the test shut-off sand samples were taken from B 7, B 11 and B 15 after about half of the sand had been blown out. The average particle size varied from 88 to 93 % of the original size. These sand samples show that the used S 9 sand was broken down into finer particles quite slowly. The used particle size was also within the right limits. For example B 15 showed a sand loss of less than 0.1 m sand per day. On the other side the other burners showed a high sand loss but most of this was probably blown out with air when the sand and water plugs were removed.

The pressure drops through the burners did not correlate to the amounts of sand except at the top and bottom limits of the sand heights of 6 and 4 m (20 and 13 feet). The pressure drop was then decreased from about 2.00 - 2.15 kg/cm^2 (28.5 - 30.6 psig) to about 1.75 - 1.90 kg/cm^2 (24.9 - 27.0 psig).

Heat distribution

The temperature readings taken in T 2, 3, 7, 8, 11, 13, 15 showed a fairly even heat distribution without any abnormal heat concentration at the cone level. The temperature was also determined inside the burner casings with a thermometer in the same holder as used in the temperature wells. By this equipment the temperature could be measured only down to the very top of the fluidized bed. It was noticable that the sand plugs in the burner casings were formed where the temperature was about 100°C (212°F) except in B 15, which below this temperature showed about 20 % higher temperature than the others. A few temperature curves in the temperature wells and inside the burner casings at different times are shown on Figs. 1 through 7.

Outline for a new test, called Gas-KL 3

Because nine of the eleven casing failures probably can be rated as weld failures a new test with five burners having casings in one length will be started in August 1960. The same burner tube coupling as in Gas-KL 2 will be used but completed with coupling tubes of 18/8 stainless steel. The difficulties with the condensing of the combustion water above the top of the fluidized bed are assumed to be overcome easier by installing 1/2" tubes inside the burner casing through which air can be blown at any time.

Närkes Kvarntorp, July 29, 1960

Bengt Persson

(Bengt Persson)

Time Date May	Hours from start	Burner amount in oper.	Remarks
1	708		14 Mcal/b-h.
2	752	6	B 15 shut off. Hole erroded out on b-tube coupling.
3	766	7	B 13 on.
4	790	8	B 15 on.
	796	6	B 7, 11, 13, 15 off. Gas-air mixture out of control. B 13, 15 on in a few minutes. B 7 b-tube coupling did not loosen. Sand above b-tube coupling in B 11.
	798	0	All burners off. Gas-air mixture out of control.
	799	6	B 2, 3, 8, 12, 13, 15 on.
5	814	7	B 7 on.
	817	8	B 11 on. 12.5 Mcal/b-h.
6	846	7	B 12 off.
	848	8	B 12 on.
8	878	7	B 15 off.
	879	8	B 15 on.
9	902	7	B 3 burner casing burned off. 14 Mcal/b-h.
	910	7	12.5 Mcal/b-h.
12	992	6	B 12 shut off for inspection.
	996	7	B 12 on.
13	1014	0	Power off.
	1016	5	B 2, 7, 8, 12, 15 on. B 11, 13 burners pulled for inspection.
	1021	6	B 13 on.
	1024	7	B 11 on.
14	1051	0	All burners off due to decrease of air volume. Air valve was partially plugged by oil and scarps. B 12 burner casing was corroded off.

Time Date May	Hours from start	Burner amount in oper.	Remarks
15	1053	5	B 2, 7, 8, 13, 15 on. B 11 b-tube coupling leaking.
16	1089	5	B 11 on. B 8 shut off for inspection.
	1091	6	B 8 on.
18	1137	5	B 2 shut off for installing of coupling tube.
	1140	6	B 2 on.
19	1160	5	B 11 shut off for installing of coupling tube.
	1168	6	B 11 on.
	1170	0	Gas-air mixture out of control.
	1171	5	B 2, 7, 8, 13, 15 on. Could not separate B 11 burner parts because coupling tube was too tight.
20	1185	6	B 11 on.
	1187	0	Shut off for cleaning of mixing valves and regulators.
	1192	6	On.
30	1422	4	B 2, B 8 burner casings burned off.
	1428	3	B 13 burner casing burned off.
	1432	0	B 7, 11, 15 shut off. B 7 burner casing leaking. The total heat input was 89,530 Mcal.

Summary of sand fluidization in Gas-KL 2 during May, 1960

Burner No.	Hours from start	Sand Amount A m	Fluidization B m	Average	Expansion B/A
B 2	708 - 817	4.0 - 6.0	12.4 - 14.3	13.4	
	817 - 1130	4.0 - 6.0	12.7 - 15.1	13.8	2.1 - 3.4
	1140 - 1422	5.1 - 6.0	14.5 - 15.7	14.9	2.4 - 2.9
B 3	708 - 817	3.7 - 6.0	12.2 - 15.5	13.8	
	817 - 902	4.3 - 6.0	13.5 - 14.3	13.8	2.3 - 3.1
B 7 x)	708 - 817	4.1 - 6.0	9.0 - 12.1	10.8	
	817 - 1150	4.0 - 6.0	10.9 - 13.9	12.5	1.8 - 2.8
	1150 - 1432	3.6 - 6.0	12.5 - 15.5	13.7	2.2 - 3.6
B 8	908 - 817		12.3 - 15.1	13.5	
	817 - 1089	4.0 - 6.0	12.6 - 15.0	14.0	2.1 - 3.3
	1091 - 1421	3.9 - 6.0	14.0 - 16.7	15.3	2.3 - 3.2
B 11	708 - 817	- 6.0	12.0 - 12.5	12.3	
	817 - 1160	5.2 - 6.0	11.7 - 14.2	12.6	2.1 - 2.7
	1185 - 1432	4.7 - 7.0	13.8 - 14.3	14.0	2.0 - 2.9
B 12 x)	708 - 817	- 6.0	10.1 - 12.5	10.9	
	817 - 992	4.0 - 6.0	9.8 - 11.8	11.0	1.6 - 3.0
	996 - 1051	4.2 - 6.0	13.0 - 15.0	14.1	2.3 - 3.2
B 13	766 - 817	- 6.0	12.3 - 13.4	12.8	
	817 - 1014	4.7 - 6.5	11.9 - 13.3	12.6	1.9 - 2.6
	1021 - 1428	4.7 - 6.0	13.5 - 15.2	14.6	2.3 - 3.1
B 15 x)	708 - 817	- 6.0	9.6 - 12.7	10.9	
	817 - 1150	5.4 - 6.0	10.9 - 14.0	12.3	1.9 - 2.4
	1150 - 1432	5.8 - 6.0	13.5 - 14.9	14.5	2.3 - 2.5

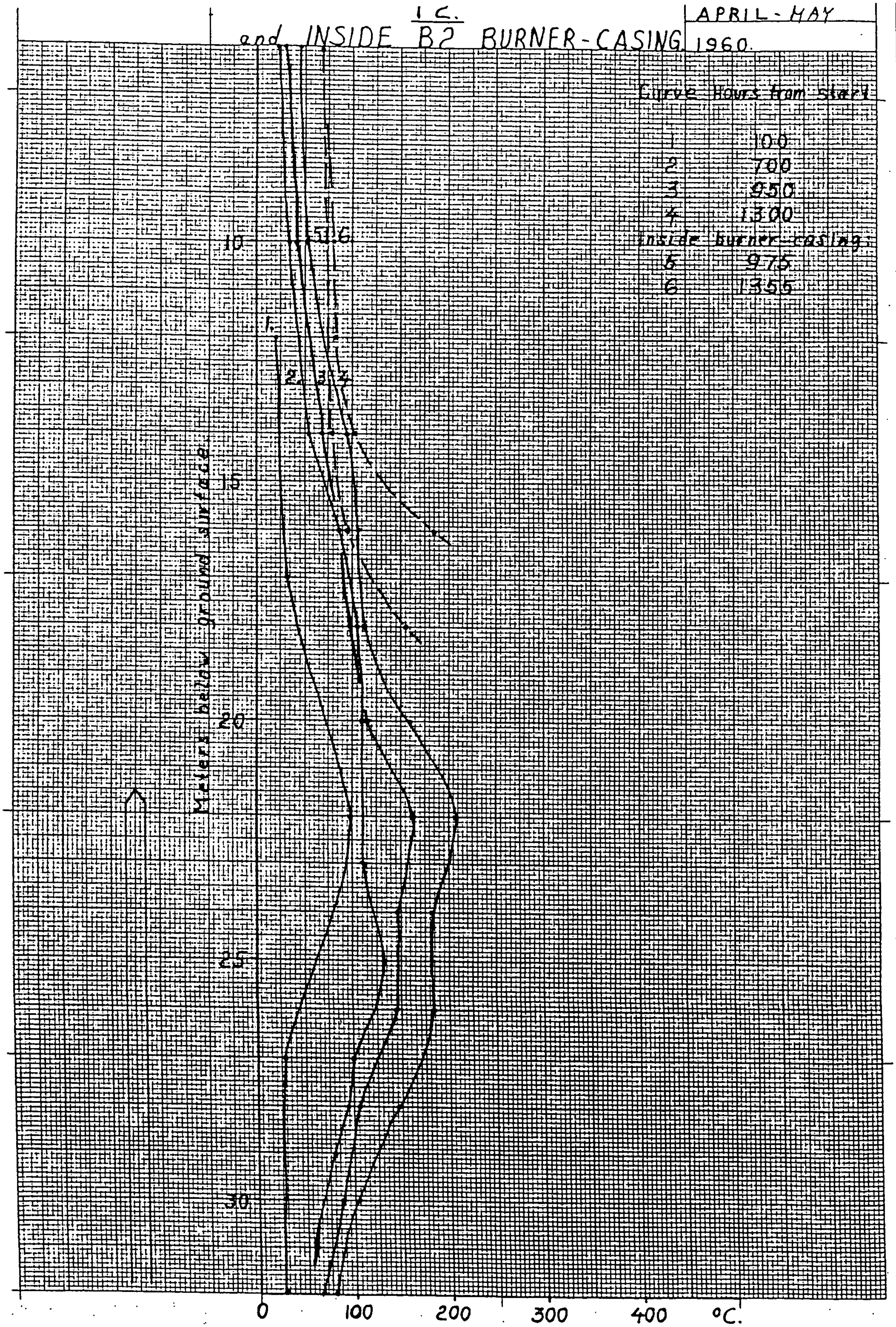
x) 8 m long burner tube.

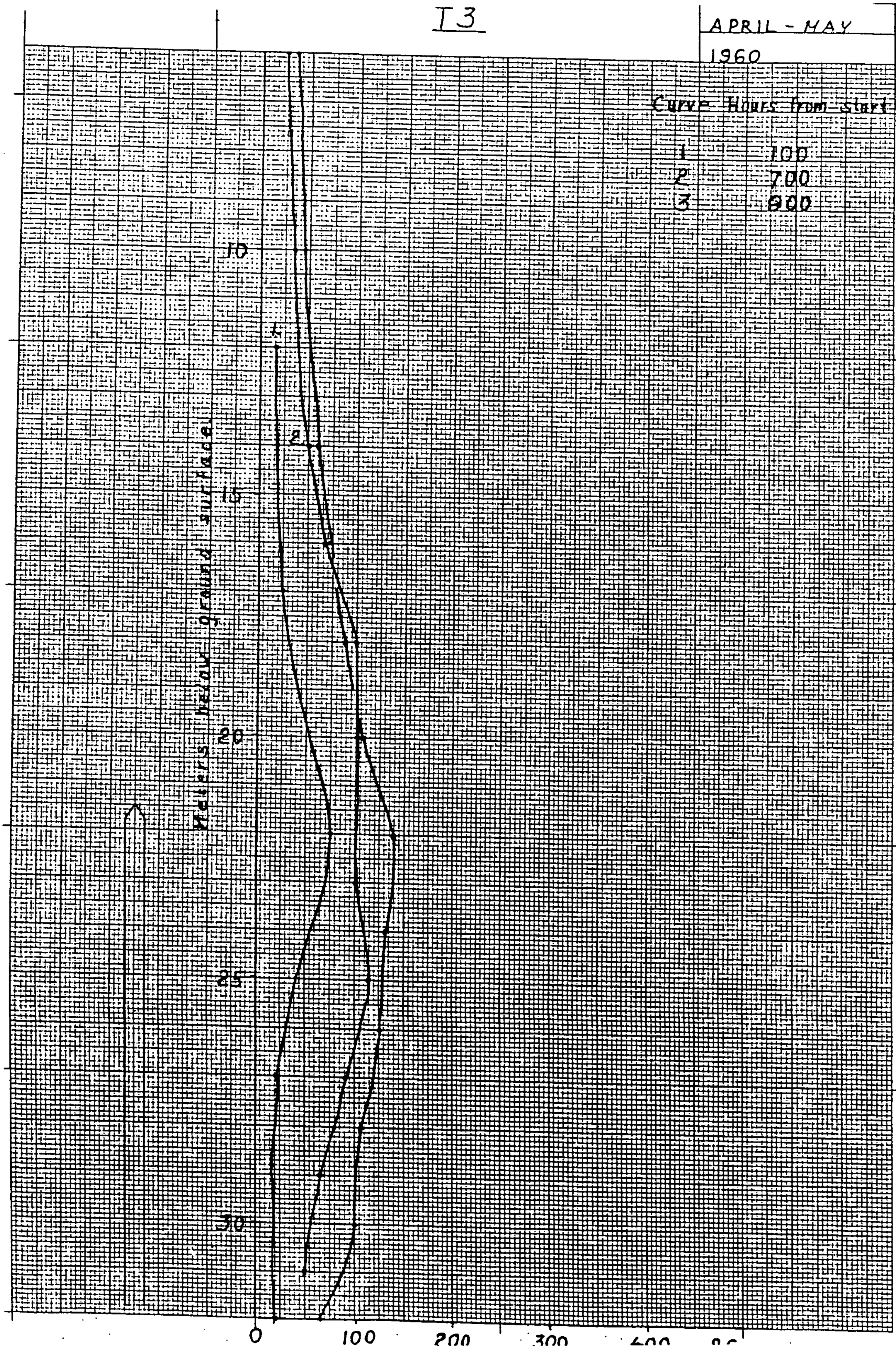
May, 1960

Sieve analyses of Gas-KL 2 burner sand

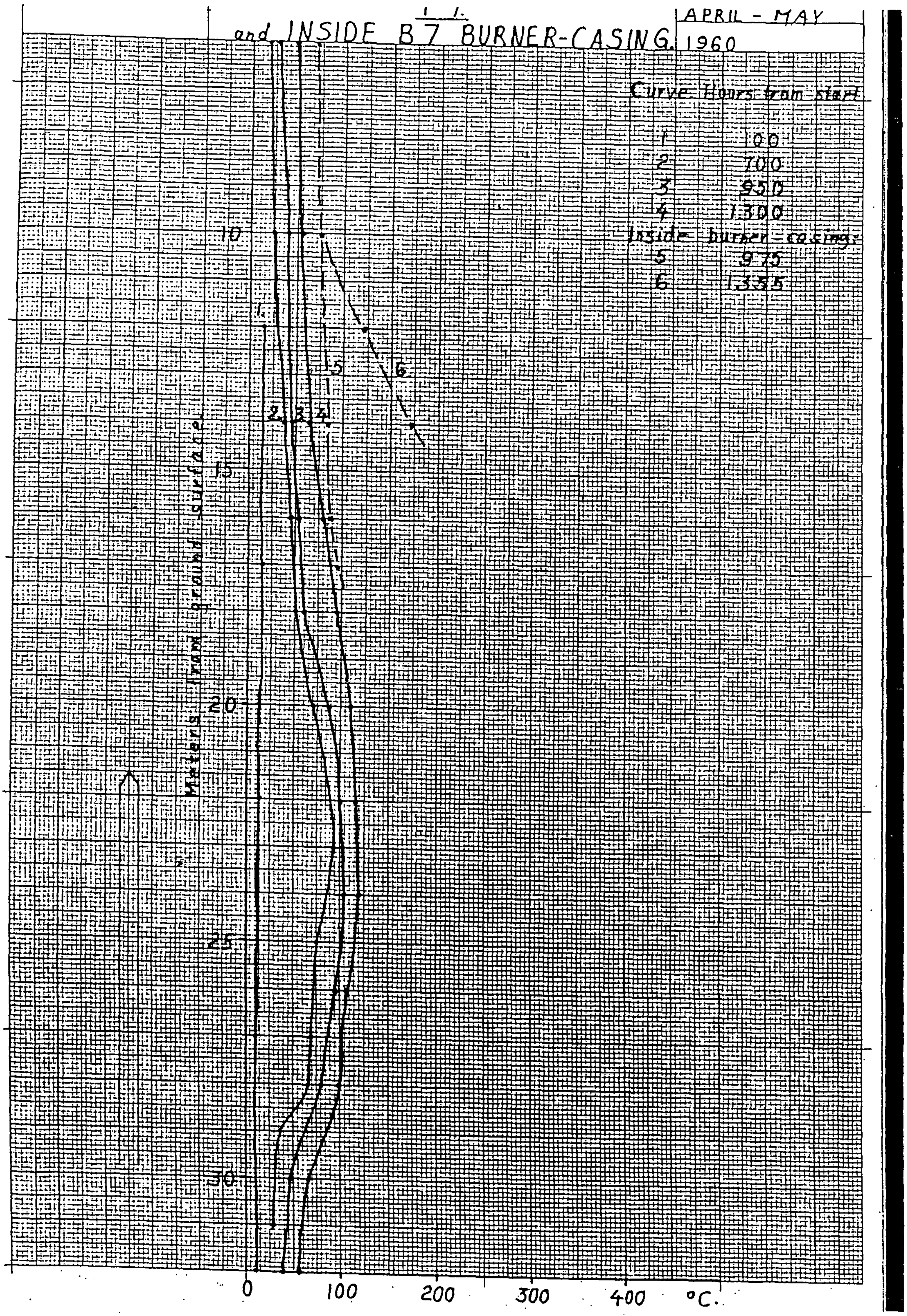
Source	% of sand size <10 mesh or <2 mm	10-18 mesh or 1-2 mm	18-35 mesh or 0.5-1 mm	>35 mesh or >0.5 mm	Average particle size, mm	% of orig. size
Top of B 2 sand bed at 970 hours	0.5	56.0	30.7	12.9	1.121	80.0
Top of B 7, 8, 11, 12, 13, 15 sand beds at 970 hours	0.7	58.7	25.8	14.8	1.135	80.8
Middle of B 7 sand bed at 1440 hours	0.2	74.6	23.7	1.5	1.308	93.1
Middle of B 11 sand bed at 1440 hours	0.2	69.9	20.1	9.8	1.234	87.9
Middle of B 7 sand bed at 1440 hours	0.5	70.0	19.6	9.9	1.239	88.1

FP/Emm
1.8. 1960.


I.C.
and INSIDE B2 BURNER-CASING
APRIL-MAY
1960
Curve Hours from start
1 100
2 700
3 950
4 1300
Inside burner-casing:
5 975
6 1355
Meters below ground surface
10
15
20
25
30
0
100
200
300
400
°C.



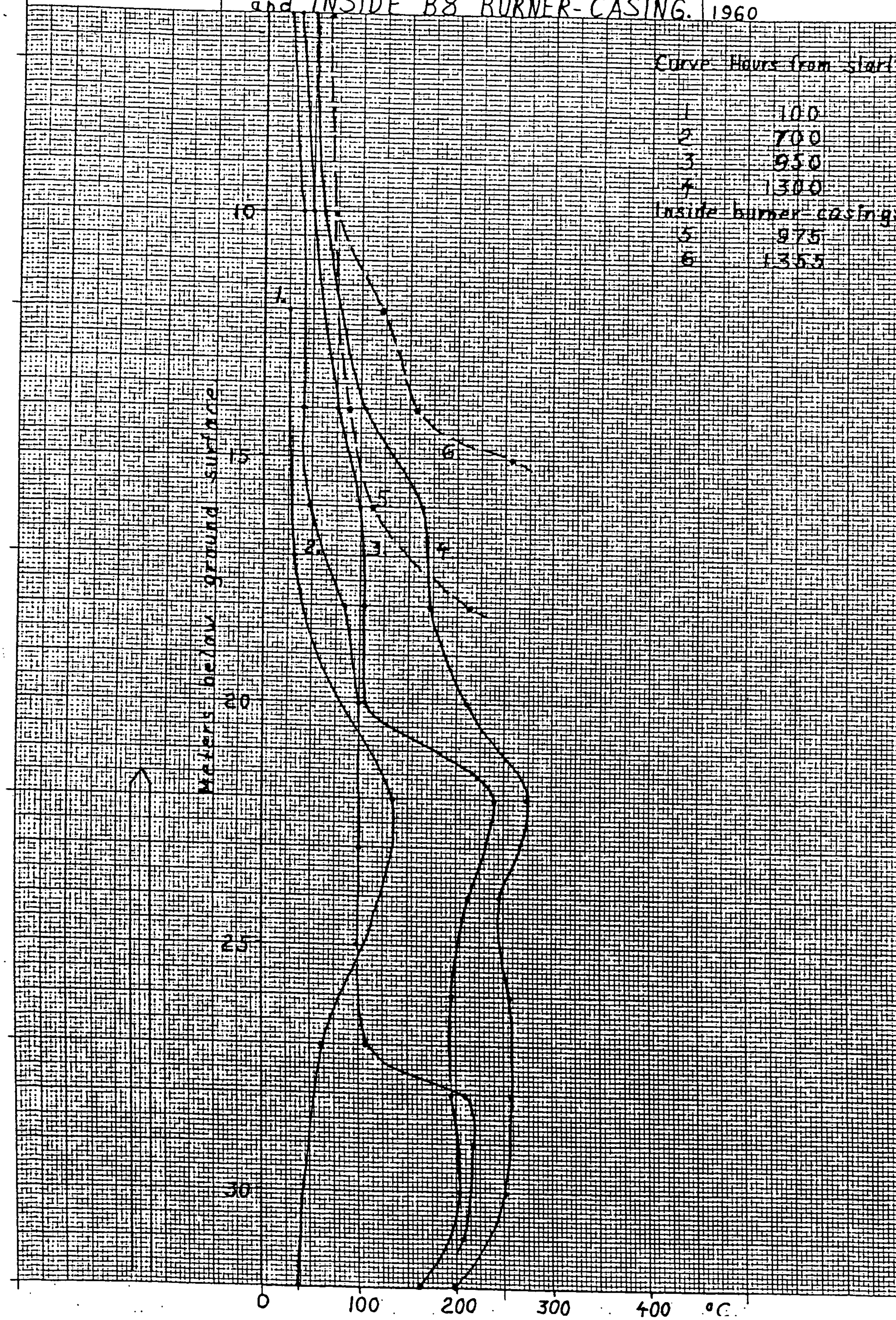
T3
APRIL - MAY
1960
Curve Hours from start
1 100
2 700
3 900
Meters below ground surface
10
15
20
25
30
0
100
200
300


and INSIDE B7 BURNER-CASING.
APRIL - MAY
1960
Curve Hours from start
1 100
2 700
3 950
4 1300
Inside burner-casing:
5 975
6 1355
Meters from ground surface
10
15
20
25
30
0
100
200
300
400
°C.
1
2
3
4
5
6

18.

and INSIDE B8 BURNER-CASING.

APRIL - MAY 1960



T11.

and INSIDE B11 BURNER-CASING.

APRIL - MAY 1960

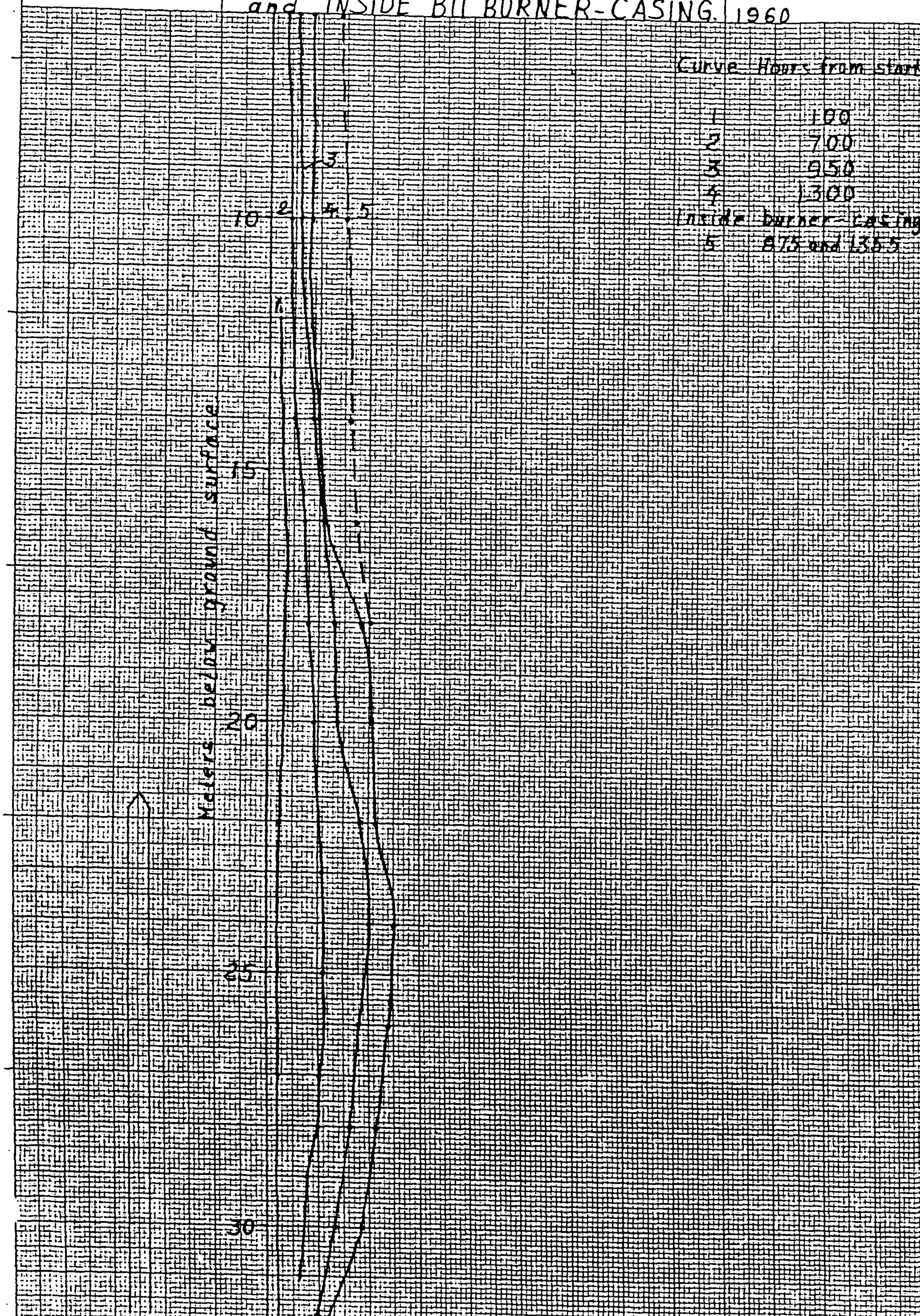
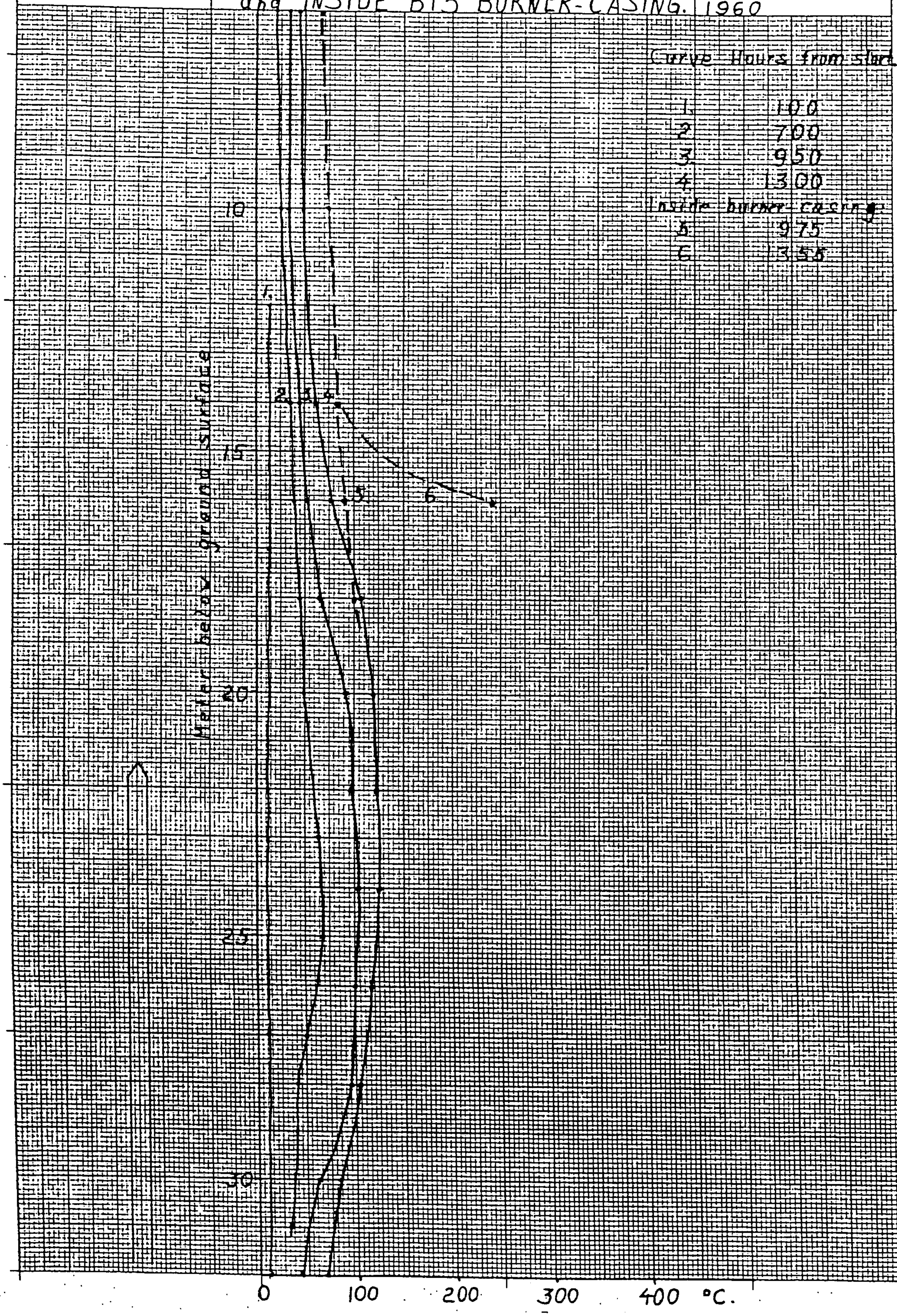
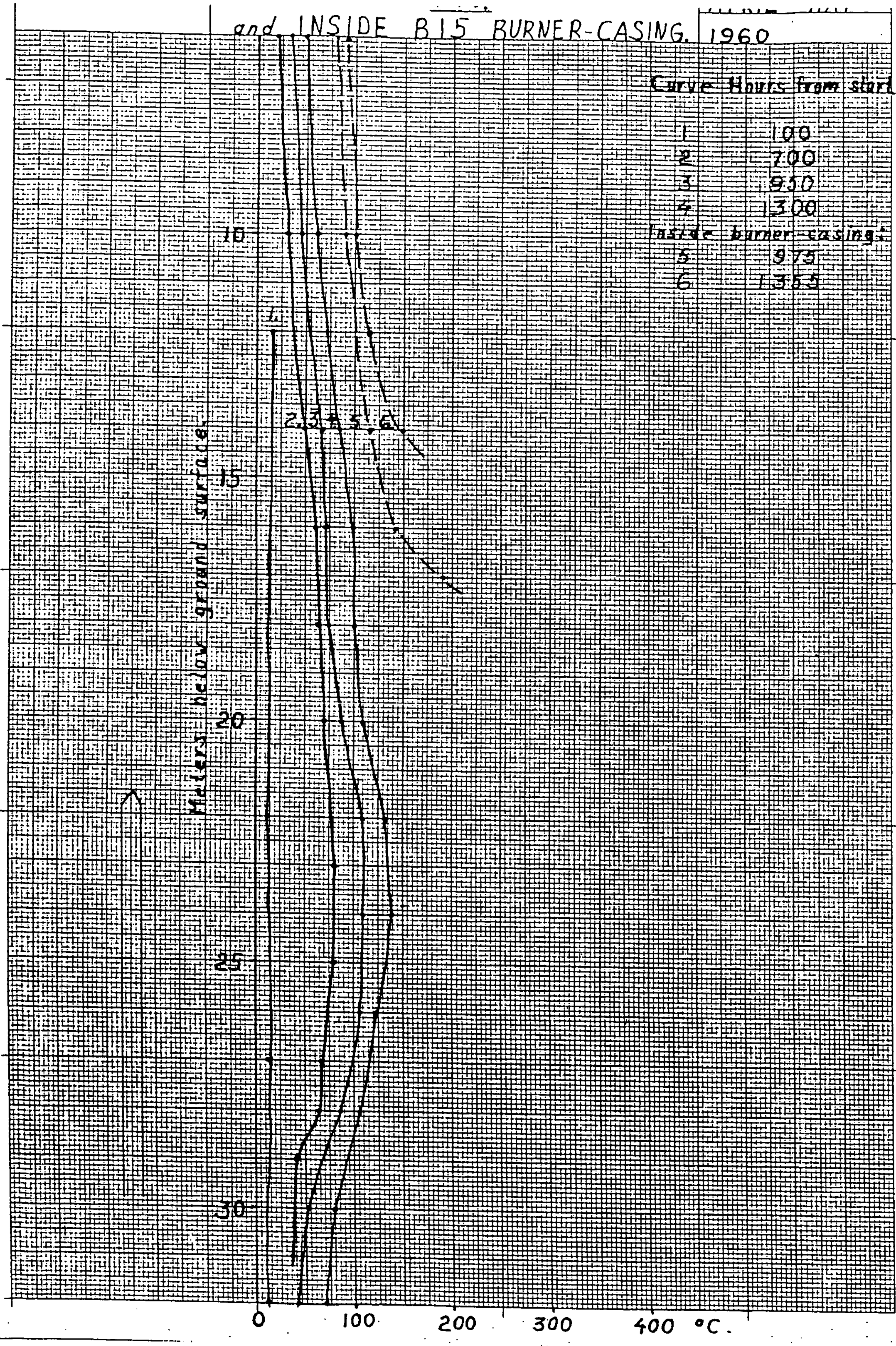


FIG.

and INSIDE B13 BURNER-CASING.

APRIL - MAY 1960




and INSIDE B15 BURNER-CASING.
1960
Curve Hours from start
1 100
2 700
3 950
4 1300
Inside burner-casing:
5 975
6 1355
Meters below ground surface
10
15
20
25
30
0
100
200
300
400 °C.
1
2 3 4 5 6

Preliminary report of Gas-KL 3

September through November, 1960

Purpose

It was concluded from the former test Gas-KL 2 that most of the casing failures were caused by weak welding seams. Therefore, it was desirable to test the burners with the casings in one length without any joint weld. It was also found that a coupling tube in the burner tube coupling stabilized the coupling. This was tested only at the end of Gas-KL 2 and more information was thus necessary. It would also be advantageous to obtain more experience about the difficulties with the condensing water and sand plugs above the top of the fluidized bed in the upper part of the burner casing.

Thus a new test was started called Gas-KL 3 in the Ljungstrom field.

Test arrangement

Five burners were placed 0.5 m (1′ 8") from each adjacing earlier drilled and set electrical heaters No. 89 through 93 in row 103. The burners were numb r d B 16 through B 20. The casings to the electrical heaters were used as temperature wells, numbered T 15 through T 20.

The burner holes were drilled to a depth of about 33 m (108′) and the 32.5 m (106′ 6") long 89 · 3.25 mm (3.50" · 0.13") seam welded casings of carbon steel were set at 32 m (105′) from the ground surface. They were sandpacked to the bottom of the holes. Thus, the burner arrangement corresponds to group I, 3 Gas-KL 2.

The same kind of supply tubes, cones and burner tubes were used as in Gas-KL 2. The burner tube was 10 m (32′ 10") long and the burner tube coupling with a 25 · 2 mm (0.99" · 0.08") coupling tube was placed at 3 m (9′ 10") below the cone.

The equipment for the fuel gas and air was the same as in Gas-KL 2.

Test operation

The five burners were first started September 6. Difficulties with the mixing equipment were soon encountered. It had to be cleaned and adjusted with a few minor changes. At new relightings it was found that the coupling tubes were

stuck in the bottom part of the burner tube. They had been bent somewhat. At last the 1.25 m (4' 1") long coupling tubes were cut off to 0.8 m (2' 8") and the lighting hole placed at 0.5 (1' 8") m below the coupling. Then it was easy to pull the burners for relighting.

Most of September was used for these different adjustments. The test was not running smooth until September 23 (398 hours).

B 16 burner casing failed on October 2 (624 hours). It was later on found out that the failure occurred in the bottom of the casing. Before this casing was set a 1 m (3') long pipe, used for rinsing the drillhole with water, was dropped. The casing was then set about 0.2 m (8") above this pipe. It could have been too close so at the heating of the casing, this expanded down to the pipe which thus pressed up the bottom plate of the casing. An unsuccessful attempt was made to tighten this leak.

B 20 cone and casing burned off on September 28 (513 hours). This was strictly a cone failure which could have been caused by a brake in the casting. At th same time a small hole was corroded out in the casing. Surprisingly, this hole could later be tightened by pressing cement through it. Therefore, the burner with a new cone was restarted on November 9 (1,526 hours) and was in operation during another 206 hours until the shut-off of the test.

B 17, 18 and 19 were running fine but with difficulties of avoiding the condensation of water in the casing above the top of the expanded sand bed. As in earlier tests the water created sand plugs, which had to be broken by blowing air through. This was mostly done by blowing air of about 4 atm (60 psig) air pressure through 1/2" pipes installed in the burner casing to the top of the expanded sand bed. At many occasions the amount of air was not enough and the water and sand plugs had to be removed with air through a 1" hose.

This water problem probably depends on the heat input. 14 Mcal per burner-hour (56,000 BTU/b-h) was used until 625 hours after start when the heat input was decreased to 12.5 Mcal per burner-hour (50,000 BTU/b-h). It was increased to 14 Mcal again at 1,384 hours. After this increase the combined water sand plugs began to cease and from 1,550 hours to 1,936 hours at the end of the test no efforts were necessary to brake loose the plugs.

At the end of the test even heat inputs of 15 and 16 Mcal p r burner-hour (60,000 - 64,000 BTU/b-h) were tried for short periods. The obtained heights of the expand d sand beds can be summariz d as follows:

12.5 Mcal/b-h	13 - 15 m	(43′ - 49′)	expanded bed
14	15 - 16	(49′ - 52′)	
15	17	(56′)	
16	20 - 21	(66′ - 69′)	

The amount of sand was varying between 5 and 6.5 m (16′ - 21′) burner casing. The expanded bed varied only somewhat with this difference of sand.

Table 1 shows the total heat input and the operation time for each burner during the following different times:

The start period September 6 - 23 (0 - 398 hours);
The main test period September 23 - November 12 (398 - 1,604 hours);
The end period November 12 - 26 (1,604 - 1,936 hours).

During the last part of the test the burners were running without operators and were only controlled occasionally from November 9 (1,540 hours). The burners were running fine but went out two times caused by regulator and power failures.

No electrical heaters were in operation after November 1. The electrical heaters from row 103 were never started. Therefore the burners did not operate with the optimum heat supply from the adjacing heaters and were thus shut off. About 11,000 to 13,000 Mcal (44 to 52 millions BTU) electrical energy was supplied to each electrical heater in rows 100 to 102. Maximum temperatures of about 200° C (400° F) were reached in the temperature wells T 17, 18, 19.

Results

At evaluating the results it has to be kept in mind that the burners were not supported by the optimum amount of heat from the adjacing electrical heaters. Therefore the expected temperature increase was not reached and the burners were thus running under somewhat milder conditions.

The burners were easy to start by adding about 3 m (10′) sand within half an hour after the start. The additional sand could then be added successively during the following 20 - 30 hours. The problem of the condensing water in the upper part of the casing is probably not so serious. It seems as this can

be avoided by keeping a high input of about 14 to 15 Mcal per burner-hour (56,000 - 60,000 BTU/b-h) during the first 1,000 to 1,500 hours. Anyway the plugs of sand and water can be blown up by high pressure air through temporarily installed tubes.

It was encouraging that three of the burners did not show any particular wear at total heat inputs of 19,000 to 22,000 Mcal (74 to 87 millions BTU). The highest total heat input reached in Gas-KL 2 was 15,000 Mcal (61 millions BTU). It should especially be pointed out that the burner tube coupling with the coupling tube showed only a minor corrosion in Gas-KL 3. Thus, the coupling tube seems to be a promising improvement of this coupling.

Närkes Kvarntorp, December 21, 1960

Bengt Persson

(Bengt Persson)

Tabl 1

Heat inputs and operation time of Gas-KL 3

Date	Hours from start	B 16			B 17			B 18			B 19			B 20	
		Heat input 10^3 Mcal (10^6 BTU)	Operation time hours	Operation time % of test time	Heat input 10^3 Mcal (10^6 BTU)	Operation time hours	Operation time % of test time	Heat input 10^3 Mcal (10^6 BTU)	Operation time hours	Operation time % of test time	Heat input 10^3 Mcal (10^6 BTU)	Operation time hours	Operation time % of test time	Heat input 10^3 Mcal (10^6 BTU)	Opera[tion time] hour[s]
Sept. 6 - 23	0 - 398	3,47 (13.8)	248	62.4	3.16 (12.6)	226	56.7	3.22 (12.8)	232	58.3	0.20 (0.8)	14	3.5	0.83 (3.3)	59
Sept. 23 - Oct. 2	398 624	3.08 (12.2)	220	97.5											
Sept. 23 - Nov. 12	398 1604				15.46 (61.4)	1189	98.6	15.43 (61.3)	1187	98.4	15.33 (60.9)	1178	97.7	2.46 (9.8)	175
Nov. 12 - 26	1604 1936				3.25 (12.9)	232	69.8	3.25 (12.9)	232	69.8	2.94 (11.7)	210	63.2	1,96 (7.8)	140
Sept. 6 - Nov. 26	0 1936	6.55 (26.0)	468	24.2	21.87 (86.9)	1647	84.9	21.90 (87.0)	1651	85.3	18.47 (73.4)	1402	72.4	5.25 (20.9)	374

Costs for the LINS-tests at the Ljungström field, Närkes Kvarntorp, conducted by Svenska Skifferolje AB.

June 1959 - June 1960.

	Invoice		Amount
June 1959			
Ahlsell & Rylander			
350 m 76 x 3 mm tube for burner casings	16113	2.231:46	
3.500 m 57 x 2,75 mm tube for gasline	"	15.747:60	
Trelleborgs Gummifabrik			
50 m 1/2" rubber hose	14906	190:--	
SSAB, drawing office			
Drawing, 18 hrs		180:--	
SSAB, workshops, labor			
Transportation and installation of compressor, 12,7 hrs		230:10	
July 1959		18.579:16	18.579:16
Björklund & Vedin			
Construction of gasline	680	2.500:--	
Ind. Gasfören.			
Pressure regulator	397	107:--	
Göte Larssons Plåtslageri			
400 pipeclamps for gasline	401	200:--	
Husky Oil Co.			
Freight for 2 boxes of burners	10954	133:64	
SSAB, field labor			
Key to drill reamer, 3,5 hrs		24:22	
Drilling of burner holes, 21,5 hrs		111:88	
Unloading of pipes, 14,0 hrs		69:26	
SSAB, drawing office			
Drawing, 9 hrs		90:--	
SSAB, workshops, labor			
Construction of slab for compressors, 18 hrs		216:--	
Installation of compressor, 5 hrs		60:--	
Misc. transportation with VW-bus, 5,5 hrs		66:--	
Transportation of compressor, 2 hrs		50:--	
" " " 2 "		32:--	
		3.660:--	22.239:16
August 1959			
Husky Oil Co.			
Freight for 2 boxes of burners	893	418:75	
Bröd. Edstrands			
42,97 m 1/4" pipe of 18/8 stainless steel	2065	498:45	

	Invoice		Amount
ÅHÅ-Produkter			
Making of 12 burners and 10 orificeplates	2240	560:50	
SSAB, field labor			
Setting of burner casings, 112,5 hrs		585:43	
Drilling of burner holes, 74 hrs		385:08	
Drilling of temp. wells and setting of temp. casings		161:23	
Transportation of pipes 3 miles, 3,5 hrs		18:92	
Welding of burner tubes, 31,5 hrs		176:30	
Turning and welding of parts for drilling, 13 hrs		90:70	
Making of pipeclamps and changing of pipe fixture, 13 hrs		90:70	
Making of funnel for sandpacking, 6,5 hrs		42:69	
Maintenenace work on pipe setting rig, 3,5 hrs		18:21	
Transportation of drilling rig		10:41	
SSAB, warehouse			
2 mercury manometers, 1 flange to orificemeter		495:--	
130,5 m pipe, 15,8 m 3" soil casings		129:21	
11 m planks, 37 m planed boards for compressor and instrument house		25:98	
290 m planks, 115 m planks, 59 m planed boards for compressor house		330:11	
3 elbows, 3 couplings, 4 nipples, 2 reducers		40:77	
5 unions, 2 nipples, 2 couplings, 10 flanges		94:05	
6 pipe bends		7:13	
6 nipples, 10 plug cock, 8 nipples		111:21	
3 flanges, 4 valves, 6 unions, 56,7 m tube, 11,1 m pipe		331:78	
1 nipple, 6 elbows		6:19	
58,5 mm pipe, 11 unions		200:66	
3 m square rod		6:51	
36 pipeclamps		134:31	
SSAB, drawing office			
Drawing, 27 hrs		270:--	
" 12,5 hrs		50:--	
SSAB, workshops, labor			
Turning of orificeplate, 5 hrs		65:--	
Making of orificeplate, 1,3 hrs		16:90	
Making of raw material for orificeplate 1,9 hrs		24:70	
Cutting of centralizers, 7 hrs		91:--	
Building of compressor house, 35,4 hrs		424:80	
Making 1 window glass, 0,5 hr		6:--	
Making 1 window sash, 1,5 hrs		13:20	
Plumbing to compressor, 9 hrs		108:--	
Misc. transport in VW-bus, 14 hrs		168:--	
" " of material, 14,5 hrs		232:--	
Compressor service, 2 hrs		50:--	
		6.489:88	28.729:04

September 1959

	Invoice	Amount
Göte Larssons Plåtslageri		
475 pipeclamps	2382	1.782:50
156 "	3387	312:--
ÅHÅ-Produkter		
Installation work on test field	2513	225:78
Björklund & Vedin		
Welding of gasline	2777	181:20
A.H. Ågren AB		
2.000 kg sand to burners	2356	196:50
Atlas Copco		
Air filter	2697	325:--
Freight	"	19:--
AB Nord. Armaturfabrikerna		
Safety valve	3328	126:--
Freight	"	7:80
Yxhults Stenhuggeri AB		
Freight by train during September	3615	176:--
SSAB, field labor		
Pulling and setting of burners, 28 hrs		145:71
Welding, 16,5 hrs		92:35
" 2,5 hrs		18:05
Installation, 6 hrs		42:27
Test operation, 115 hrs		561:80
SSAB, warehouse		
4 elbows, 26 m pipe		90:44
1 package welding rods		27:57
2 bushings		1:03
1 window glass		3:38
0,5 m pipe		0:69
1 1/4" tee		0:54
1 safety valve		51:--
1 tee		0:54
4 1/4" drain valves to orifice meters		18:35
6 Ermetocouplings, 2 1/4" valves		15:20
6 m pipe		7:92
55 kg steel plate		39:33
4 flanges		21:01
193 m pipe		367:28
6 couplings, 6 nipples		4:49
2 valves, 2 pipe bends, 1,5 m pipe		20:94
18 elbows, 12 m pipe		37:62
10 couplings		8:80
9 elbows, 5 unions, 6 nipples		48:95
2 plug cocks, 2 nipples		20:55
6 plugs		2:71
1 plug cock, 1 nipple		5:82
10 tees, 1 globe valve, 10 nipples, 10 plug cocks		101:20
Returns to warehouse	./.	253:37
SSAB, drawing office		
Drawings, 7,5 hrs		52:50
" 9 hrs		36:--

	Invoice		Amount
SSAB, field labor			
Plumbing to compressor station, 45 hrs		540:--	
Making window glass, 0,5 hr		6:--	
Transportation, 0,75 hr		12:--	
" of pipes from Kumla, 7 miles, 4,25 hrs		68:--	
		5.568:45	34.297:49
October 1959			
Samuelsson & Bonnier			
200 pipe stands, making culverts for gasline	3829	2.838:40	
Ind. Gasfören.			
1 pressure regulator	4196	105:--	
Freight	"	2:--	
ÅHÅ-Produkter			
Misc. work on burners	4305	420:05	
Andrew Hollingworth			
Hosenipples	4901	14:03	
Malte Eurenius			
Car compensation	2646	54:60	
SSAB, field labor			
Setting and pulling of burners, 75,5 hrs		392:89	
Operation and maintenence of test, 144 hrs		749:35	
-"- 20 hrs		11:93	
-"- 9 hrs		43:97	
Turning and welding, 8,5 hrs		60:32	
Repair of thermometer reels, 4,5 hrs		30:37	
SSAB, warehouse			
11,5 m pipe		15:94	
2 plugs		4:28	
1 elbow, 2 nipples		1:38	
1 stop cock of cast steel, 1 stop cock of brass		111:39	
1 globe valve		25:69	
1 Sarco TD-50 steamtrap, 1 steamtrap of brass		151:36	
1 bushing		0:33	
1 "		0:26	
7,6 m pipe, 3 m pipe		14:80	
1 nipple		1:15	
10 sacks cement		56:55	
1 pkg welding rods		28:33	
54 m pipe		174:04	
0,3 kg plate of stainless steel		1:44	
1 tee, bushings, 0,4 m screen		2:52	
SSAB, workshops, labor			
Installation of Ljungman compressor, 40,5 hrs		526:50	
Cutting of centralizers, 2,8 hrs		36:40	
Welding of belts, 0,4 hr		5:20	
Cashing of base plates to compressor, 11,2 hrs		134:40	
Transportation, VW-bus, 2 hrs		24:--	
" 2,25 hrs		36:--	
" 1 hr		16:--	
" compressor, 2,3 hrs		57:50	
" air tank, 0,8 hr		20:--	
		6.168:37	40.465:86

	Invoice		Amount
November 1959			
Björklund & Vedin			
Laying of gasline	5413	439:66	
-"-	5479	5.726:80	
-"- and material	5480	4.475:73	
ÅHÅ-Produkter			
Making of 10 burner tube couplings	6157	304:02	
Westin & Backlund			
1 Norgren pressure regulator	6009	140:--	
Freight	"	1:70	
1 Norgren pressure regulator	6794	260:--	
Freight		2:40	
Kuntze & Co.			
50 1/2" packer rings of neopren	6051	11:--	
Postage	"	0:50	
A.H. Ågren AB			
700 kg sand to burners	6251	68:77	
Freight	6799	108:10	
AB Nord. Armaturfabrikerna			
1 temperature gauge	6341	141:--	
Freight	"	3:--	
Malte Eurenius			
Car compensation		179:01	
SSAB, field labor			
Operation and misc. work on test, 354 hrs		1.842:15	
Installation of compressor, instruments, water separator, 25 hrs		169:92	
Changing of gas-air lines and burner tubes, 28,5 hrs		199:44	
Misc. installation work, 17,5 hrs		97:95	
SSAB, warehouse			
4 ball bearings		50:71	
10 sacks cement		41:91	
Planks, roofing cardboard, nails, etc.		179:97	
10 m cupper tubing		23:87	
8 elbows, 1 rubber hose		14:20	
3 bushings		2:74	
3 m pipe, 3 angles		5:58	
2 plug cocks, 2 couplings		6:18	
SSAB, drawing office			
Drawing, 7,5 hrs		67:50	
SSAB, workshops, labor			
Installation of Ljungman compressor, 38,4 hrs		499:20	
Cutting of centralizers, 3 hrs		39:--	
Rebuilding of compressor house, 26,1 hrs		313:20	
Service on compressor motor, 0,5 hr		6:--	
Service on compressor, painting, 7,9 hrs		79:--	
Transp rtation, VW-bus, 0,5 hr		6:--	
" 0,75 hr		12:--	
Misc. test work, 9 hrs		72:--	
		15.590:21	56.056:07

	Invoice		Amount
December 1959			
Wåhrmes Åkeri			
Truck transportation	8633	143:10	
AB Nord. Armaturfabrikerna			
2 water dischargers to water separator	8274	92:50	
AB Atlas Copco			
Air compressor NT8, used for demonstration			
Air compressor NT8	8362	2.409:60	
		3.014:40	
Sv. Diamantborrn. AB			
Core barrell 5766-2			
Freight	8610	173:--	
	"	9:--	
Yxhults Stenhuggeri AB			
Freight by train during December		60:--	
Malte Eurenius			
Car compensation		50:70	
SSAB			
Salaries and payroll burden for test supervisor		2.107:--	
SSAB, field labor			
Operation of test, 81 hrs		421:51	
-"- 116,5 hrs		649:55	
Deassembly and transportation of Salzgitter drilling rig, 8 miles, 4,8 hrs		249:78	
-"- 8,5 hrs		45:95	
Pipe cutting, 19,5 hrs		165:11	
Installation of compressor, 7 hrs		42:90	
-"- 7 hrs		36:75	
SSAB, warehouse			
23 m of 12 mm wire		26:82	
4 m V-belt		20:32	
63 kg cast iron		63:76	
25 l lube oil		26:40	
Returns to warehouse		./. 104:15	
SSAB, workshops, labor			
Turning and fitting of pulley, 11,4 hrs		148:20	
Turning of drill rods, 5,6 hrs		72:80	
Welding on drilling rig, 1,1 hrs		14:30	
Transportation, VV-bus, 0,5 hr		6:--	
" 0,76 hr		12:16	
" crane truck, 8 hrs		200:--	
		10.157:46	66.213:53
January 1960			
ÅHÅ-Produkter			
Making of 4 drill bits, 2 drill collars	9138	507:70	
Turning of drill bit	9961	93:78	
Making of burner tube coupling	9962	43:82	
Rudolph Grave AB			
30 thermomet rs 0-450°C	9173	616:65	

AB Samuelsson & Bonnier			
Rent of bulldozer D7	9385	143:61	
Fagersta Bruks AB			
475 m 89 x 82,5 mm tubes for burner casings	9614	3.594:15	
Diamantborrn. AB			
1 core barrell	9668	146:--	
Sales tax + freight	"	15:13	
Währmes Åkeri			
Truck transportations		138:80	
SSAB			
Salary and payroll burden for test supervisor	11362	2.591:--	
SSAB, field labor			
Drilling of burner holes, 233 hrs		1.534:17	
-"- 139,5 hrs		918:51	
Set-up of drilling rig, 27 hrs		182:24	
Making of thermometer holders, 13,5 hrs		91:11	
Pipe cutting, 3 hrs		16:80	
SSAB, warehouse			
6,1 m tube, 100 bit pins of hard metal		262:06	
3,5 kg brass		15:83	
9 pipe joints for cables		5:84	
SSAB, drawing office			
Drawing, 10,5 hrs		94:50	
SSAB, workshops, labor			
Making of orificeplates, 10,2 hrs		132:60	
Transportation, VW-bus, 2,5 hrs		30:--	
" 1,5 hrs		24:--	
		11.198:30	77.411:83
February 1960			
Gustafsson & Görtz			
2 cutting dies	11512	7:61	
Honeywell AB			
65 m thermocouples	10258	210:--	
45 m extension wire	11055	157:50	
Sv. Diamantborrn. AB			
Sales tax on invoice 2406	10287	7:27	
Uddeholms AB			
Plates of stainless steel for centralizers	10519	238:--	
AB Uddeholm Agent.			
3/8" pipe of stainless steel	10704	346:90	
Discount on invoice 10704	11615	./. 31:42	
15 1/4" couplings of stainless steel	10865	31:26	
Sandvikens Jernverks AB			
60 m 3/8" pipe of 18/8 stainless steel	10838	856:--	
16 m 89 x 3,25 mm tube of 18/8 stainless steel	10839	2.063:16	

	Invoice		Amount
AB Nord. Armaturfabrik rna			
Temperature gauge	11150	123:91	
Yxhults Stenhuggeri AB			
Freights by train during February	11456	16:--	
AB Sv. Godscentraler			
Freights by trucks	11580	38:50	
SSAB			
Salary and payroll burden for test supervisor	11402	2.591:--	
SSAB, field labor			
Transportation and connection of compressor, 12 hrs		69:79	
Misc. installation work, 13,5 hrs		88:89	
Drilling of burner holes, 72 hrs		474:08	
-"- 36 hrs		237:04	
Retransportation of drilling rig, 3 miles, 5,5 hrs		36:53	
Rinsing of drill holes, 2 hrs		10:41	
Disconnection and transportation of Ljungman compressor, 3 hrs		20:49	
Unloading of pipes, 8 hrs		39:51	
Test operation, 94 hrs		524:10	
SSAB, warehouse			
6 m wire, 3 pkgs welding rods, 0,5 kg square iron		78:81	
20 kg rubber plate		279:84	
11 kg square iron		8:47	
2,1 m screen		17:18	
SSAB, drawing office			
Drawing, 5,5 hrs		49:50	
SSAB, workshops, labor			
Cutting of 2 orifice plates, 0,7 hr		9:10	
Turning of 2 orifice plates, 6,8 hrs		88:40	
Misc. shop work, 138,2 hrs		1.796:60	
Making of 2 sand packing funnels, 49,3 hrs		640:90	
Transportation of drilling rig, 3 miles, 9 hrs		144:--	
Unloading of pipes, 4 hrs		64:--	
Removal of drilling rig, 6,2 hrs		155:--	
		11.488:33	88.900:16

March 1960

	Invoice		Amount
ÅHÅ-Produkter			
Manufacture of 15 burner tube couplings	11824	305:09	
Ahsell & Rylander			
20,3 m 146 x 4,5 mm tube for soil casing	11625	433:86	
AB Atlas Copco			
2 belt pullies	12064	310:--	
AB Nord. Armaturfabrikerna			
2 pressure gauges	12620	43:71	
Honeywell AB			
Correction of invoice for February 1960	11055	8:50	
SSAB			
Salary and payroll burden for test supervisor		2.591:--	

	Invoice		Amount
SSAB, field labor			
Test operation, 476 hrs		2.653:95	
Installation of compressor, 14 hrs		91:55	
Misc. installation work, 84 hrs		470:13	
Compensation for overtime " 4 hrs		22:30	
SSAB, warehouse		55:03	
585 ceramic insulators to thermocouples, 1 welding rod			
203 m pipe		108:82	
9 V-belts, 5 stuffing boxes, 1 sack cement		578:36	
8 kg Silix cement, 5 V-belts, 50 kg plates of carbon steel		108:13	
12 plates wellboard		90:49	
6 el. heaters		77:88	
2 flanges		15:84	
200 m el. cable		2:77	
5 stuffing boxes, 5 plug cocks		2.967:80	
		107:15	
SSAB, workshops, labor			
Service on compressors, 6,4 hrs		83:20	
Misc. repair and welding, 289,5 hrs		3.763:50	
Cutting of steel plates, 1 hr		13:--	
Lumber work on cabin for operators, 14,6 hrs		175:20	
Completion of thermocouples, 17,7 hrs		212:40	
Transportation of cable, 2,2 hrs		22:--	
" VW-bus, 1 hr		12:--	
" 1,6 hrs		25:60	
		15.349:26	104.249:42

April 1960

	Invoice		Amount
N. Elektr. AB			
Electrical cable to compressors	13089	108:--	
ÅHÅ-Produkter			
Fabrication of burner tube coupling with burner tube	13142	126:50	
AB Prod. mtrl			
2 tubes Anit-Scuffing paste	13556	20:03	
Bengt Persson			
Car compensation during January - April 1960	7747	320:32	
SSAB			
Salary and payroll burden for test supervisor	11525	2.591:--	
SSAB, field labor			
Operation of test, 734 hrs		4.092:42	
Compensation for overtime		753:89	
Service of compressor, 3 hrs		24:23	
SSAB, warehouse			
1 plug		0:33	
0,4 m screen		1:56	
0,4 m "		1:46	
2 welding rods		13:67	

	Invoice		Amount
SSAB, workshops, labor			
Repair of compressor, 87,2 hrs		1.133:60	
" " compressor fan, 1 hr		13:--	
Helper to test operator, 6,5 hrs		78:--	
Transportation, VW-bus, 5 hrs		60:--	
		9.338:01	113.587:43
May 1960			
AB Björklund & Vedin			
Deduction for earlier finished work	15063	./. 37:84	
Labor for laying of gasline	15194	65:10	
A. Hollingworth & Co.			
2 universal pliers	14962	25:--	
A. H. Ågren AB			
2 tons sand to burners	14381	216:--	
Truck transportation of sand	15157	250:--	
ÅHÅ-Produkter			
3 burner tube couplings	15410	138:69	
AB Atlas Copco			
Compressor valve	15483	57:--	
SSAB			
Salary and payroll burden for test supervisor	11569	2.591:--	
SSAB, field labor			
Test operation, 640,5 hrs		3.571:11	
" 10 hrs		55:97	
Compensation for overtime		426:14	
SSAB, warehouse			
7 m tube		26:80	
SSAB, workshops, labor			
Making of 2 orifice plates, 4,7 hrs		61:10	
Service on compressor, 1,5 hrs		19:50	
Transportation, VW-bus, 1 hr		12:--	
		7.477:57	121.065:--
June 1960			
Atlas Copco			
Valves and springs to compressors	16470	511:--	
Sandviksstål			
9 m 25 x 2 mm tube for coupling tubes of 18/8 stainless steel	15905	212:50	
Samuelsson & Bonnier			
Laying of gasline	16990	176:31	
Atlas Copco			
15 washers for compressor	16781	67:50	
Freight	"	1:40	
Bengt Persson			
Car compensation	9037	100:--	
SSAB			
Salaries and payroll burden for test supervisor	11661	3.696:--	

SSAB, field labor		
Drilling of burner holes for		
GAS-KL3, 120 hrs	813:07	
64 hrs	433:64	
SSAB, warehouse		
1 tube 16944	7:70	
Spare parts to compressor	31:68	
12 drill bit knives of hard metal	862:18	
SSAB, drawing office		
Salary, 6,5 hrs	58:50	
SSAB, workshops, labor		
Transportation of drilling rig		
2 miles, 9 hrs	144:--	
" 5,5 hrs	55:--	
" 7 hrs	175:--	
	7.345:48	128.410:48
Balance since June 1959		128.410:48

Costs for the LINS-tests at the Ljungström field, Närkes Kvarntorp, conducted by Svenska Skifferolje AB.

July 1960 - November 1960.

July 1960

	Invoice		Amount
Sandviksstål Sales tax on stainless pipes, invoice 15905 (June 1960)	233	2:36	
AB Nordiska Armaturfabrikerna Pressure gauge	765	24:74	
SSAB Salaries and payroll burden for test supervisor		2,766:--	
SSAB, field labor Field installation of Gas-KL 3, 54 hrs		312:55	
SSAB, workshops, labor Gas- and air line installation, 77.6 hrs		1,008:80	
SSAB, warehouse 7 sacks cement		30:03	
98 m 1" tubing for air line		350:35	
		4,494:83	4,494:83

August 1960

	Invoice		Amount
ÅHÅ-Produkter 1 experimental burner tube coupling	1486	146:63	
Virsbo Bruks AB 5 pieces 32.5 meter joints of 89 x 3.25 mm tubing for burner casing	1667	1,706:25	
Yxhults Stenhuggeri AB Freights	2241	361:50	
SSAB Salaries and payroll burden for test supervisor		2,766:--	
SSAB, field labor Field installation, 224 hrs		1,292:48	
SSAB, workshops, labor Compressor maintenance, 1.1 hrs		14:30	
SSAB, warehouse 2 safety valves		11:--	
2 couplings		1:12	
		6,299:28	10,794:11

September 1960	Invoice		Amount
Yxhults Stenhuggeri AB			
Freights	3530	176:--	
Hällabrottets Bilstation			
Taxi	3597	17:15	
Axel H. Ågren AB			
2,000 kg sand for burners	3894	216:--	
SSAB			
Salaries and payroll burden for test supervisor		2,766:--	
SSAB, field labor			
Installation and repair of gas-, air lines, 137 hrs		910:79	
Test operation, 788 hrs		4,913:09	
SSAB, workshops, labor			
Making of 5 orifice plates for burners, 3.8 hrs		49:40	
Repair of compressor pulley, 6.7 hrs		87:10	
Repair of radio, 17.1 hrs		222:30	
Transportation, 1.7 hrs		30:60	
SSAB, warehouse			
3.2 kg brass		22:88	
10 couplings		20:13	
2 pressure gauges		23:10	
3 m 10 x 1 mm tubing		1:--	
3 valve keys		4:74	
		9,460:28	20,254:39
October 1960			
SSAB, Bengt Persson			
Car compensation	2200	63:84	
SSAB, field labor			
Test operation, 771.5 hrs		4,977:63	
SSAB, warehouse			
LPG-burner and container		126:47	
		5,167:94	25,422:33
November 1960			
Hällabrottets Bilstation			
Taxi	6591	9:65	
"	6593	20:40	
SSAB, Gösta Eriksson			
Destroyed clothes	2980	248:65	
SSAB, Bengt Persson			
Car compensation	3668	62:70	
SSAB, field labor			
Test operation, 226 hrs		1,425:35	
SSAB, workshops, labor			
Repair of compressor pulley, 1.3 hrs		16:90	
		1,783:65	27,205:98
Balance since July 1960			27,205:98